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| 62. | "Cantaloupes" | By H. H. Griffin |
| 63. | Sugar Beets"—(A Resume of the Work Done by the Agricultural Experiment Station of Colorado) | By W. P. Headden |
| 64. | "Press Bulletins, Nos. 1 to 11." | |
| 65. | "A Soil Study. Part III, The Soil" | By W. P. Headden |
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| 67. | "The Distribution of Water. Powers and Duties of Irrigation Officials in Colorado" | By H. N. Haynes |

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| 21. | October 9 to October 15—Summary | By L. G. Carpenter |

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254247

**Bulletin 62.** **April, 1901.**

The Agricultural Experiment Station

OF THE

Agricultural College of Colorado.

# CANTALOUPES.

—BY—

**H. H. GRIFFIN.**

PUBLISHED BY THE EXPERIMENT STATION
Fort Collins, Colorado.
1901.

# THE AGRICULTURAL EXPERIMENT STATION,

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"NETTED GEM" Cantaloupes, grown at Rockyford, Colo.

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# THE CANTALOUPE.

BY H. H. GRIFFIN.

## INTRODUCTION.

The Arkansas Valley of Colorado has for some years been famous for its cantaloupes.

During the season of 1900, 780 cars were shipped, which represents the product from about 2,500 acres.

The cantaloupe is known as the "Rocky Ford" from the town that has led in the industry. The variety grown is the Netted Gem, which Burpee claims to have the distinction of originating. Through environment it has become so perfected in the vicinity of Rocky Ford as to be unsurpassed in quality, and needs only to be introduced in any market to at once take possession of it.

The melon plant is of rank growth and succulent tissue. It thrives best under conditions of high temperature, dry air, and continuous sunshine, and a deep, warm, sandy loam soil. It is as delicate in constitution as in texture. It does not adapt itself readily to varying conditions nor to sudden climatic changes, and its tissue offers little resistance to the attacks of fungi.

### CULTIVATION.

Were it not that there are many amateurs growing this crop, owing to the rapid settling of the lands in the Arkansas valley of Colorado, this bulletin need not deal with this phase of the subject.

The first planting is done from the first to the tenth of May; seldom any advantage is gained by putting the seed in earlier than May 1st. The land is put in good condition by rather deep plowing, harrowing and leveling. Furrows are then run with a shovel plow from 6 to 7 feet apart and the seed planted by the side of the furrow, making the hills from 5 to 6 feet apart in the rows. Uniformity of planting facilitates cultivation, as for a considerable time the field may be cultivated in both directions. Care must be exercised not to plant the seed too deep. The depth should not exceed one inch.

Some growers irrigate the furrows and plant afterwards, while others plant and then irrigate, permitting the water to reach the seed by percolation. I prefer subirrigation to germinate the seed, as the soil is apt to become crusted and dry if it is handled and pressed after irrigation.

Plenty of seed should be used—from 10 to 15 seeds to each hill—and when the plants have put forth four leaves, thin to three plants for each hill. Cultivate and hoe sufficiently to secure good tilth until the vines run well, or are from two to three feet across the hill. Then the irrigating furrows should be run and cultivation cease, giving such hoeing as will keep down weeds.

### SEED.

Good seed is a prime requisite for success with the cantaloupe, but not enough attention has been paid to the selection of it. Few have made any systematic selection of seed, looking well to the shape, size, solidity, depth of flesh, seed cavity, color of flesh and quality. Many have bought from dealers who knew little of the quality of seed sold, and the result is that many melons sold as "Rocky Ford" are not up to the standard. The effect of poor seed is more apparent in those districts in which there are many amateur growers, than where the older growers predominate.

A pure Rocky Ford cantaloupe when ripe should have a silver colored netting which is lace-like in appearance. The skin should be green turning to a peculiar gray color when the melon is fit for shipping. The flesh should be green in color and so sweet and luscious that it may be eaten close to the rind. The melon should have a small seed cavity and the portion of the flesh immediately surrounding it be slightly tinged with yellow. The melon should weigh about one and one-half pounds and be very solid and firm.

The cantaloupe growers should save seed from the very best melons, for in this way only can the quality be maintained or improved. No grower should save seed for his planting without testing the quality of the melon. Occasionally a melon may be perfect in appearance, but not of first rate quality.

### HARVESTING.

Much seed is shipped to points outside the state and the product from this seed is shipped to market as "Rocky Ford" melons. "Rocky Ford" melons, so called, are on the market about the time the melon is setting on the vines in the Arkansas valley. A few melons are shipped the first week in August, but heavy shipments do not commence before the middle of the month. The melons are picked into sacks, carried over the shoulders of the pickers, and are at once taken to the shade—packing sheds being made for the purpose—where they are crated. The standard crate holds forty-five perfect melons, in three tiers of fifteen melons each, and weighs about sixty-nine pounds. There are also used, to some extent, the two-layer crate, which is two-thirds the size of the standard, and the "pony" crate holding forty-five melons, but smaller than those of standard size. The standard crate is (inside measurement) 22 inches long, 12 inches wide and 13 inches deep.

When it is proper time to pick for shipment, the stem slightly parts from the melon. No stem tissue should adhere to the melon, but there should be a smooth surface where the stem was attached. The netting and skin has a peculiar grayish appearance, which is easily distinguished when one becomes accustomed to picking.

The cantaloupe is very perishable and rapid transportation, in refrigerator cars, is required. By this means melons of good quality are placed in all of the markets of the eastern states. The shipping period (from the same vines) should extend over not less than thirty days; a more rapid ripening than this is generally indicative of unhealthy conditions. As high as 300 crates per acre have been taken from alfalfa sod, but 100 to 150 crates of marketable melons per acre is considered a good yield.

## IRRIGATION.

The essential thing in irrigating is to keep the water confined to the furrow, reaching the roots only by percolation. This keeps the soil in good condition, does not cover the vines with mud, and leaves the fruit in dry condition. If the water stands on the fruit it is apt to induce decay or cause uncolored or soft spots, which make the product unsalable. It is common to irrigate every ten days, paying little attention to the needs of the plant. The tendency is to irrigate too often early in the season.

The most water is required about the time the blossoms commence to set well, previous to this giving only enough to keep the plant growing well. When the plant commences to bloom profusely, irrigate thoroughly and afterwards give only so much water as will keep the plant in good thrifty condition. A too moist condition is apt to increase the spread of any fungus trouble.

In 1899 three plats were used to test the effect of irrigation on quality and production. One plat had seven irrigations, June 19, 30, July 10, August 1, 17, 26, and September 4; another three irrigations, June 30, August 1, and September 4; and a third plat one irrigation, July 10. Heavy rains occurred in July, and considerable rain fell in August.

The plat irrigated but once did not yield so heavily as the others; the vines and fruit were smaller, but the fruit was of better quality. The plats numbered one and two yielded about the same, and as far as could be judged, the quality was the same. Evidently, plat No. 1 received twice as much water as was necessary.

## FERTILIZERS.

Virgin soils produce good melons both in quality and quantity, but fertilization is soon a necessity. Since fungus troubles have become annoying, it is not advisable to apply any heating manure to the soil just previous to growing cantaloupes, as it has a tendency to increase the trouble.

A comparative trial in 1899 with melons grown on alfalfa sod, on cropped land manured with well rotted barnyard manure in the hill, and on cropped land fertilized with bone dust in the hill, showed the best results from the alfalfa. The product was nearly doubled, the quality was better, and the ability to resist fungus troubles greater. Alfalfa sod brings maximum returns, and in turn the melon easily subdues the alfalfa and puts the land in splendid condition for succeeding crops.

## TRANSPLANTING.

A test was made in 1899 to note to what extent hot bed propagation may hasten maturity and how successfully it may be performed. The seed was put in the hot beds April 3. Some of the seed was put in cans, so arranged that the plants could be taken from them without disturbing the roots, while others were put in the bed without any support. It was found quite difficult to transplant them when the roots were at all disturbed. Fully 95 per cent of those set from the cans grew, while only about 50 per cent of those taken from the bed without support survived. May 8, the first plants were taken from the bed and set in the open field. The first seed planting in the open field was April 29 and the second May 10.

The first ripe melon was taken from the transplanted vines August 17, only one day earlier than melons grown on ground fertilized with alfalfa or manure, and only four days earlier than those grown without any fertilizer.

However, they ripened (in quantity) faster, and for the next ten days gave more ripe melons than any other planting.

### DISEASE OF THE VINE.

Until recently the industry has advanced at a rapid pace, no disease or insect pest causing trouble of any consequence.

A blight or rust first attracted attention in a few fields in 1896, and there was a slight increase in its spread in 1897. No one gave it serious thought at first, and it was not until it became prevalent and the damage serious, that anyone realized to what extent it might cripple the industry. My attention was first called to it in 1898, when it became so prevalent in some fields as to do much injury to the crop at about the time the melons were ripe.

It first appeared in well defined centers on fields that had been cropped with melons continuously for some years.. In 1899 it was apparent that the disease diminished as we receded from these centers, and, in most cases, it did not appear on the remote fields until later in the season.

The leaves were found to be covered with numerous brown spots, giving them a rusty appearance. The spots ran together, eventually killing the leaf. The stem was also covered with spots, and in some cases the melon was affected, the diseased tissue often extending to the heart of the melon.

Leaves and stems were sent to Prof. Crandall, who pronounced the trouble due to a fungus (*macrosporium*), but sent the specimens to Ellis and Everhart, who pronounced it a new species, naming it "*cucumerium*."

To the casual observer, the cantaloupe blight, which is caused by a true parasitic fungus, first appears as a number of brown spots about the size of a pin head upon the leaves in the center of the hill. A careful examination of the younger leaves shows where the fungus has been at work, sometime before it is apparent by the brown appearance. It can be seen where the leaf tissue has been eaten away, and when the injured tissue dies, then it is that the brown appearance occurs. These spots gradually enlarge until they may attain a diameter of half an inch, and the number sufficient to envelop the leaf and cause its death. In some badly affected fields can be seen spots of all gradations in size, from those just forming on the young leaves to those so large as to destroy the older leaf.

During nearly the whole season the cantaloupe is putting forth new growth that is very succulent, and this parasite may be doing incalculable injury long before the grower is aware of its presence. This is especially true if the weather conditions are moist and favorable to its increase and spread.

### EXPERIMENNTS IN 1899 FOR THE CONTROL OF THE DISEASE.

Observing in 1898 that the disease was apparent only on certain fields, I made a collection of seed from these for planting the following year, to see if it was communicated by the seed. This seed was planted in the spring of 1899 away from other melons for the purpose above mentioned, and for some preliminary spray work for the control of the disease.

Three rows, each 250 feet long, were planted, the middle one being reserved for spraying with the Bordeaux mixture, using the others as checks. The row was sprayed June 22, and again June 30, with Bordeaux mixture—4 pounds of copper sulphate (blue stone) to 40 gallons of water. At this time there was something on the vines that looked like blight. The next spraying was done the 22d of July, at which time the blight was in evidence and spreading rapidly. The row was again sprayed July 31 and August 11.

The weather previous to June 19 had been very dry. Subsequent observations have shown that the spread of the disease, previous to this time, would not have been rapid enough to be discerned, even if the weather had been moist.

After June 20, rain and dews were plentiful; seven inches of rain fell during July, 5.14 inches of this in the week commencing July 14. The vines were completely submerged and the spray, no doubt, mostly destroyed. The weather conditions following were very favorable to the spread of the disease.

Owing to the weather conditions during July, it was not apparent that any benefit was secured from the two early sprayings, but a decided benefit was obtained from those made after July 22.

The sprayed vines remained green and in a growing condition long after the others had succumbed to the disease, and fruit of good quality was picked from them the first week in September. Two weeks previous to this the last merchantable melons were taken from the unsprayed vines and they, at all times, were inferior in quality to those picked from the sprayed vines. They ripened prematurely and the taste was insipid; this alone being sufficient guide to determine from which vines the melons came. It could not be said that the infection came from the seed, for these vines were no worse infected with the blight than other melons on the station property or in the adjacent country. Some of the seed was held over for planting in 1900, and the results are like those mentioned.

All of the fields in the vicinity of Rocky Ford were more or less affected with the disease, the spread being much more rapid than anyone anticipated. This caused us to inaugurate experimental work, late in the season, for its control.

There were, at the station, seven rows of cantaloupes, each 275 feet long, on alfalfa sod. One of these was sprayed with the Bordeaux mixture July 31, and again August 11. This work confirmed the results enumerated above.

Another row was sprayed with the ammoniacal copper carbonate solution (1 oz. to 6 gallons of water) August 4, and again August 8 and 11. Some benefit was secured from this spray, in the same way it was with the Bordeaux mixture, but it was not so pronounced, nor does the spray adhere so well to the plant.

Mr. I. D. Hale had some June planted melons which we secured for experimental purposes. They were sprayed with the Bordeaux mixture July 27, and again July 31 and August 11.

About one-eighth of an acre of melons was sprayed for G. W. Swink, August 15 and 16. Owing to press of work only one application was given these vines, but the benefit from the spray was quite marked when compared with the remainder of of the field.

August 21 we sprayed about one acre of late melons at I. D. Hale's, in which the blight was very bad; it appeared as though no returns could be secured from the field. Even after the vines were thus affected there was a marked improvement in the appearance of the vines, and the fruit did not deteriorate in quality nearly so rapidly as in an unsprayed portion of the field.

Mr. C. S. Fenlason had about 1¾ acres of late melons which were secured to spray, to verify previous results and to further study the cost of the work. The vines were very large, completely covering the ground.

A barrel of spray mixture was put in a slip scraper which was pulled backwards, and two rows taken on each side. The work was done August 22 and 23. Twenty-two pounds of copper sulphate were used to make the spray. It required three men and one horse thirteen hours (together with a boy about two hours to turn the vines) to complete the work. The cost was estimated at $6.75 per acre.

Three hundred crates of good melons were sold from the field. Mr. Fenlason thinks the spray saved the crop from destruction. A few vines in this field were not sprayed and the advance of the disease on these was very noticeable. An adjoining field of melons so succumbed to the disease as to be of little value. The results of the year were of one accord; confirming the benefits from the spray as above mentioned.

## EXPERIMENTS OF 1900.

The cantaloupe season was very dry and hot, and hence extremely favorable to the vine and unfavorable to the spread of the disease, so that the results have not been so marked as was the case in 1899, when rain was prevalent.

May 8 about six-sevenths of an acre of alfalfa sod was planted to cantaloupes, it being the intention to spray .portions of it at stated intervals for the purpose of testing what number of sprayings would be the most efficient. June 11 the blight seemed to be making its appearance and the vines as yet not running. The same appearance was also found in other fields. June 13 the most of this patch was sprayed with Bordeaux mixture, July 11 sprayed the second time, and July 31 a portion of them sprayed for the third time.

The weather continued extremely dry and hot during July and August, and in but few places was there any rapid spread of the disease. There was no appreciable benefit from the third spraying.

Comparing the sprayed vines with checks and with adjoining unsprayed fields, there was an appreciable difference in the appearance of the vines, in the quality of the fruit, and the manner in which it ripened. During the last of August, the fruit on the sprayed vines was ripening slowly, while the unsprayed vines were giving up their fruit rapidly.

About four acres of melons, belonging to leasers on the station, were used for experimental purposes. Two acres of this field were sprayed June 14 while the vines were quite small, but few of them running. A second spraying was given them from July 7 to 12, at which time they were running considerable.

A third acre was sprayed July 28 for the first time, which was done for the purpose of noting the effect of late spraying. The blight was showing considerably in the center of the hills, but not spreading to any appreciable extent. After this spraying there was a peculiar appearance of the edges of the leaf (which to some might be alarming). Much of the portion assuming this appearance was brown at the time of spraying, but the centers remained green and the leaves retained their vitality, which was not the case with those unsprayed. This appearance of the edge of the leaf did not occur with those sprayed early, and its appearance is something for which I am not able to account. The remaining acre was not sprayed, for the purpose of a check upon the work.

The most noticeable feature to the parties picking the product from the field was the rapidity with which the unsprayed portion ripened its fruit. Soon after harvesting commenced the yield on this acre was twice as great as on an equal area of sprayed vines, and the quality was not so good. The melons were ripe and picked on this acre fully two weeks before they were on the other three acres. Those having the field in charge were in doubt, when the work commenced, whether there was any efficacy in the spray, but the ripening of the fruit dispelled any such doubt. There was an appreciable difference in the appearance of the vines, and this was discernable for some distance. People who saw the vines early in September would remark as to their health and vigor, and they continued to bear until frost.

Owing to the continued dry weather, the two early sprayings seemed to be all that was required, and were preferable to the one spraying done later. Had moist conditions arisen, it is probable that one or two more sprayings would have been necessary. However, the results from the late work gave evidence that good results can be secured from the late applications.

What has been said is further substantiated by results in other fields near by, in which the vines and crop were, at one time, more promising, but (due to the diseased conditions) ripened their fruit too rapidly, unevenly, and the quality was undesirable. On these fields the spread of the disease from day to day was apparent during the latter part of August and the first week of September.

An ordinary field of cantaloupes should not yield, during the height of the season, more than twelve crates of marketable melons per acre per day, but on some diseased fields it was not uncommon for more than twice that amount to be taken.

As a further test of the efficacy of the Bordeaux spray, four acres were sprayed in the field belonging to John Deweese. The first application was made June 18, and the second July 7, it being the intention to give a third, but press of work prevented it. One row was left through the center as a check, and the results showed a decided benefit to the vines and the ripening of the fruit. This was especially marked when comparison was made with an adjoining field that was planted later, but which matured its fruit earlier, owing to the disease.

Mr. Deweese feels that the spraying saved a considerable part of his crop. His greatest yield from the four acres did not exceed 50 crates per day, in a total yield of about 600 crates. When the season was nearly closed and the vines had been tramped and injured, the benefit, from the appearance of the leaves, was still apparent.

I had under observation four fields, in which spraying had been done by farmers who were incited to do the work by the results of the previous year. Some were highly pleased with the results, and in no case was there a failure to derive some benefit.

I wish to emphasize what has been said in regard to the benefit on the quality of the fruit—the value of the spray is not by any means to the vines alone. It keeps the vine in better health, and the necessary vitality is secured for the proper development of the fruit.

### COST OF SPRAYING.

A record of expense on the field of John Deweese for labor and material is as follows: June 18, 4 hours with 3 men, 1 team and 1½ barrels of spray mixture. July 7, 9 hours with 3 men, 1 team and 3½ barrels of spray mixture. An estimated total of $9.80 for two sprayings on the four acres.

The cost of spraying the two acres on the station, twice, is as follows: June 14, 1½ hours with 3 men, 1 team and 1 barrel of spray mixture. July 7 to 12, 2¾ hours with 3 men, 1 team and 1⅓ barrels of spray. The acre sprayed July 28 required 3 hours with 3 men, 1 team and 1½ barrels of spray, together with 1 hour for 1 man to turn the vines. This makes an average cost of $4.47 for spraying an acre three times. The vines varied in size from those just running to vines from 3 to 4 feet across.

These estimates, together with those for 1899 at Mr. Fenlason's, cover the cost at all stages of the melon's growth, and from this one can tell approximately what the cost will be, taking into consideration the size of the vines. The price of copper sulphate (blue stone) is assumed to be ten cents per pound in these estimates.

Our appliance for doing the work in 1900 was a platform arranged on two wheels of a grain drill, upon which was a barrel containing a spray pump. Two lengths of hose were attached to the pump, sufficient to cover from 4 to 6 rows at a time, depending upon their size. The double-trees were spread to correspond with the width of the wheels and allowed the team and cart to spread over one row.

### ACTION OF THE FUNGICIDE.

The object in applying the fungicide is to destroy the fungus without injuring the plant tissue. Further infection will be prevented and the tissue that the parasite would otherwise appropriate will be left to perform the functions of the plant.

The Bordeaux mixture is a combination of copper sulphate (blue stone), lime and water. The lime unites with the sulphuric acid, forming gypsum, and the copper is left in an insoluble condition which the gypsum tends to cement to the leaf. The carbonic acid of the air and the ammonia of the rain and dew dissolve slight amounts of the copper. It is very essential, when preparing this mixture, to use plenty of lime—an excess will do no harm. Experiments have shown that when an excess is used the copper is slower dissolved and, consequently, held on the plant longer. There are a number of ways the copper may act upon the fungus.

The spores may be prevented from germinating by inhibitory action; the spores may be killed outright before germination has commenced; the germ may be so weakened as to be unable to enter the host plant; or the presence of the copper on the leaf may impede the fruiting of the fungus already within the tissue of the plant. I believe the efficacy of the spray is due to the destruction of a considerable portion of the fungus growth present and to the prevention of the germination of the spores upon the new tissue. That the spray quickly prevents the enlargement of the spots is plainly to be seen.

The spores of the fungus, no doubt, germinate, grow and produce spores in a few days, but this period of growth may be hastened or greatly retarded by the weather conditions that prevail, and for this reason the results may vary, according as one is fortunate in applying the spray at just the time when it may be most destructive to the fungus. The development of spores apparently takes place faster in late than in early season, which, no doubt, accounts for the greater rapidity of its spread later in the season.

### EFFECT OF WEATHER CONDITIONS.

The season of 1899, being alternately wet and dry, afforded an opportunity to study the effect of weather upon the development of the fungus. When moist conditions prevailed, its spread was so rapid that it was plainly apparent, but dry weather at once checked it.

The number of sprayings required, and the time at which the spraying should be done, will have to be regulated largely by the weather conditions. When it is remembered that there may be, under favorable conditions, many successive crops (so to speak) of the fungus, and that moist, humid conditions are the most favorable for its growth, the grower will have to be guided by the weather in choosing the time for making the application.

The grower is mostly interested in preserving the leaves in the center of the hill, and for the purpose of doing this we think it well to give one or two sprayings about the time the vines commence running. The leaves in the center of the hill give protection to the major portion of the marketable melons.

The season of 1900 was extremely dry and may be considered as unfavorable for the blight as any season could be, and yet the disease was prevalent: While it did not develop to such a degree as to greatly impair the quality of the fruit in the majority of fields, yet in most instances there was more or less injury. In some fields the shipping season was shortened fully one-half, and the product was of inferior quality.

It is far preferable that weather conditions should keep the disease under control every year, but as the disease was prevalent in 1900, the farmer must expect to be obliged to cope with it under the weather conditions that usually prevail.

The farmer must not think, from what has been said in the preceding pages, that perfect immunity is secured by the use of the spray. All that can be hoped for is such control of the disease that melons of good quality may be secured, and the shipping season prolonged to near the same period that it would be if perfectly healthy conditions prevailed.

The subject is not exhausted in this report, but we have done enough work to warrant giving information to the farmer, that he may be able to cope with the trouble to the fullest extent that our knowledge, at present, will enable him to do.

### PREVALENCE OF THE BLIGHT.

No evidence could be secured in 1899 that the disease occurred in any other locality than that of Rocky Ford. In 1900 I found it in all parts of the valley, with the possible exception of Pueblo. Many farmers are yet totally ignorant of its appearance, especially when it is not present in sufficient quantity to cause any rapid deterioration of the crop. A farmer, whose field was badly infested with lice and blight, cited the fact that he had shipped 200 crates per acre from the field. Inquiry revealed the fact that the shipping period had not extended over more than two weeks, and that many melons of inferior quality had been taken because, just at that time, the supply of melons was not equal to the demands of the market.

### INJURY TO BEES.

Many hives of bees stood near one of the fields treated. The apiarist found no dead bees, nor could it be seen that any harm resulted to the bees. The blossoms of the melons live only three or four days, so that no great number of sprayed blossoms are on the plant at any one time. Most of the flowers are well protected by the leaves, so that but little of the spray reaches the center of the flower.

### FORMULA FOR MAKING THE SPRAY.

Dissolve 4 lbs. of copper sulphate (blue stone).
Slake 4 lbs. of fresh lime.

When the lime has become cool drain off the milk, adding it to the copper sulphate solution; then dilute with water until there are 40 gallons of the mixture. These proportions we have found to be about right, but care must be exercised to use plenty of lime, or otherwise the acid will burn the foliage. It is better to err on the part of too much lime than not enough. A stronger solution can be used with impunity, but we have found as good results from this as from the stronger.

## POLLINATION.

The number of flowers born by a single melon vine is something astonishing. This is no less striking than the disparity existing between the male and female flowers. An account was kept on six vines from June 27, the time of blooming, until July 13, at which time the vines had become so interlapped that individual vines could not be distinguished.

The table shows the dates on which the flowers were counted and the number of flowers that had formed at each time. The total number of male flowers formed was 3,075 and the number of female was 253; an average to each hill of 512 male and 42 female flowers to July 13:

| Date. | No. of Male Flowers. | No. of Female Flowers. |
|---|---|---|
| June 27 | 203 | 1 |
| June 30 | 338 | 11 |
| July 3 | 474 | 28 |
| July 7 | 755 | 95 |
| July 10 | 660 | 87 |
| July 13 | 645 | 31 |

It must be remembered that the vines continue to bloom profusely until late in August and melons may ripen that are set about the middle of August.

Twenty ripe melons to each vine is considered a heavy yield. In the above table we have more than 40 female flowers (to each hill) produced in the first two weeks of the blossoming period.

The first blossom appeared on June 27, and the first ripe melon was taken August 11. It takes about six weeks from the time of the setting for the fruit to ripen. Some farmers become alarmed when the first flowers that are formed drop without setting fruit, but the figures reveal the fact that the most of these are not fruit bearing flowers.

## INSECT PESTS OF THE CANTALOUPE.

*Flea beetle*—This is a small black beetle that devours the leaf soon after the melons are up. Dusting the plants with air slaked lime in early morning when they are damp, or spraying them with a mixture of 1 lb. of Paris green and 1 lb. of lime to 150 gallons of water, will remedy the trouble.

*Striped cucumber beetle*—This little striped insect is familiar to all, appearing in the spring soon after the melons are up. It has not appeared at the station since June, 1898, at which time trials for its control were cut short by a severe hail storm. I have seen good results from dusting the plants with Paris green in air slacked lime, but it is only a repellant, and hence the effect is temporary. It will drive them away for a time, but they may return with the next passing wind. In the short space of time we were enabled to combat it, we found kerosene emulsion quite effective. It acts as a repellant and kills with sufficient contact.

In Bulletin 158 of the Geneva (N. Y.) station, Bordeaux mixture was found to be the most efficient of many remedies tried. From a knowledge of its repellant properties, we are of the opinion that it will do all that is claimed for it. Its use will be a double one—for the insect and the blight. The insect is not present every year, but is very destructive when it does appear.

*Geometer or measuring worm*—This worm did much harm in 1900 by eating away the parenchyma of the leaf from the under side. It appeared about June 18 and was very near the color of the leaf, and exceedingly small. It was sometimes difficult to discern, and did much injury before many were aware of its presence. These worms are numerous every year on lettuce, cabbage, etc., but last year was the first time I have known them to attack cantaloupes. I noticed when we had sprayed with Bordeaux mixture for the blight, that but few of the worms were present.

We also used a spray of Paris green, 1 lb. and lime, 1 lb. to 150 gallons of water, which was effective. In using Bordeaux mixture for the blight the poison can be added to lessen the numbers of the insect, and thus apply a remedy for both evils at the same time.

*Melon louse*—This is the only insect that may cause alarm to the melon growers. In the eastern part of the valley it has secured such a hold that drastic measures will probably have to be taken for its suppression. I saw many melon fields in 1900 almost ruined by this insect. The insects were so numerous that the vines over whole fields were black from the excretion of honey-dew. They were so numerous as to cause inconvenience to the pickers, and yet there were many growers not aware that the insect was present in the field. The lice were sapping the vitality of the vines and destroying the quality of the product.

The insect breeds and feeds upon a great variety of plants, many of which are the common weeds of our fields. Winged forms will appear and migrate to the melons. The lice reproduce so rapidly that once they become established it may be only a short time until the whole field is infested.

Probably the best remedy is a preventive one, which consists in keeping the weeds cleared from surrounding fields, and the burning or plowing under of all vines and rubbish in the fall. Close watch should be kept early in the season, when hoeing and thinning, for any appearance of the insect.

It is a small, green insect that attaches itself to the under side of the leaf. Close observation is necessary to discern it when it first appears. The insect secures its sustenance by sucking the sap from the leaf, and only contact remedies, such as kerosene emulsion, will be of service.

If but few hills are attacked, they may be destroyed, but this is not desirable. If the field becomes infested with this insect, spray the under side of the leaves thoroughly with the kerosene emulsion (diluted 30 times) to keep it in check. As soon as the melons are harvested, put in the plow with rolling coulter attached and turn the vines under deeply. Do not use the same land to grow melons the succeeding year.

**Bulletin 63.** **April, 1901**

The Agricultural Experiment Station

OF THE

Agricultural College of Colorado.

# SUGAR BEETS.

## A RÉSUMÉ OF THE WORK DONE BY THE AGRICULTURAL EXPERIMENT STATION OF COLORADO.

—BY—

WILLIAM P. HEADDEN.

PUBLISHED BY THE EXPERIMENT STATION
Fort Collins, Colorado.
1901.

# The Agricultural Experiment Station

FORT COLLINS, COLORADO.

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# INTRODUCTORY.

BY THE DIRECTOR.

Since 1889 the Colorado Experiment Station has issued ten bulletins relating to sugar beets, eight of which have been devoted entirely and two partially to the study. Nearly all of these bulletins are now out of print, but demands still continue for the information contained in them. It is not desirable to reprint these bulletins, yet many of the investigations and conclusions are still pertinent, and it is believed that a summary of these bulletins to render the results accessible will be of much use, and incidentally serve to maintain the credit of the Station for the pioneer work on this subject which it has done in this State, the extent of which is realized by few. The bulletin places the facts developed in the published reports of this Station in compact form, and while attempting to summarize our own publications referred to, it does not attempt to summarize the work of the other stations or of the Department of Agriculture on the same subject.

This early and continuous work of the Station carried on since 1888, and supported in 1898, as it has been, by various interests, especially of the Denver Chamber of Commerce and the C. & S. R. R., has been an important factor in the location of the industry in Colorado on a firm foundation. These investigations have given the data necessary in order that sugar beet factories should be justified. At this time three factories (Grand Junction, Rockyford, and Sugar City) are in operation in the State. Another (at Loveland) is in active construction, and several more are in contemplation for 1902. The industry has every promise of being of much importance to the State, and especially valuable as it does not interfere with any other. The results already reached show that it finds in Colorado, as has been indicated in the early reports of the Experiment Station, a state well adapted to the industry.

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7. Potatoes and Sugar Beets. April, 1889. Profs. Cassidy and O'Brine.
11. Sugar Beets. April, 1890. Director Ingersoll and Dr. O'Brine.
14. Progress Bulletin on Sugar Beets. January, 1891. Dr. O'Brine.
21. Sugar Beets; Potatoes; Fruit Raising. October, 1892. F. L. Watrous.
36. Sugar Beets. March, 1897. Prof. Cooke and Dr. Headden.
42. Sugar Beets in Colorado in 1897. February, 1898. Prof. Cooke and Dr. Headden.
46. A Soil Study. Part I. The Crop Grown: Sugar Beets. June, 1898. Dr. Headden.
51. Sugar Beets in Colorado in 1898. March, 1899. Prof. Cooke.
57. Farm Notes. Alfalfa; Corn; Potatoes; Sugar Beets. July, 1900. Prof. Cooke.
58. A Soil Study. Part II. The Crop Grown: Sugar Beets. August, 1900. Dr. Headden.

PRESS BULLETINS.

1. The Sugar Beet Caterpillar. August, 1899. Prof. Gillette.
3. The Beet Army-Worm. May, 1900. Prof. Gillette.

Also, references in each of the thirteen Annual Reports of the Station.

# SUGAR BEETS.

## A RÉSUMÉ OF THE PUBLISHED WORK OF THE AGRICULTURAL EXPERIMENT STATION OF COLORADO.

BY WILLIAM P. HEADDEN, PH. D.

The first experiments made in the State of Colorado to determine the feasibility of growing sugar beets for the manufacture of sugar on a commercial scale were those made at the Experiment Station at Fort Collins in 1888. These were undertaken by Professors Cassidy and O'Brine at the instigation of the late C. L. Ingersoll, Director of the Station. Three varieties were experimented with. The percentage of sugar was quite satisfactory, the authors making the yield of cane sugar from 4,250 to 7,318 pounds per acre.

The object of these experiments is evident from the closing paragraphs of bulletin No. 7,* in which the work is recorded:

> "From the above it will be seen that there is quite a wide variation in sugar content in the four varieties tried last season. Enough, however, has been developed to create a lively interest in the cultivation of the sugar beet in this State for the purposes of sugar production—"

From the publication of the results of these first experiments, in April 1889, to the present time, the Station has issued eight other publications on this subject, only one of which republished any of the results contained in previous bulletins.

The work on this subject has taken two directions, cultural and chemical. Bulletins 11, 46, and 58 are devoted to considerations of the latter class; Nos. 7, 14, 21, 36, 42, 51, and 57 almost exclusively to cultural studies, No. 14 alone deviating from this line in containing a statement of the Director and Chemist in regard to the state of the industry in 1890.

In No. 14 the question of the relation between the size of the beet and its sugar content was discussed, and the suggestion made that the size of the beets could be controlled by thick seeding and judicious thinning.

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* Potatoes and Sugar Beets. April, 1889. Profs. Cassidy and O'Brine.

The results given are uniform in showing that small beets, such as weigh from one to three ounces, are richer than large ones, thirty to forty ounces in weight, by two per cent. or more.

The conclusion of this bulletin indicates that the author had the general question of the adaptability of Colorado to the production of sugar beets in view rather than any cultural problem, for he says, "*We believe that it has been established that the soil and climate of Colorado are favorable to the production of sugar beets, and that they can be successfully and profitably raised to the advantage, both of the farmer and manufacturer.*"

Mr. Frank Watrous, in charge of the substation at Rockyford' grew beets in 1890, '91, and '92, and records the results of his experiments in bulletin No. 21. The season of 1890 was spent in groping after facts, and the product, though encouraging, was not large. The yield obtained ranged from eight to seventeen tons per acre. Some of these yields were from half acre plots, others estimated from single rows.

In 1891 an experiment in irrigating beets was made, from which Mr. Watrous concludes that, in an ordinary season, one irrigation during the growing season is sufficient to produce the best results both as to tonnage per acre and saccharine matter contained. Four plots of one-fourth acre each were planted to Vilmorin beets. Plot 1 was not irrigated; plot 2 was irrigated once; plot 3 was irrigated twice; and plot 4 was irrigated three times. The dates of irrigation are not given. The results are:

Plot 1. Yield: 9 tons per acre. Sugar: 14.25 per cent. Purity: 80.5 per cent.

Plot 2. Yield: 10.8 tons per acre. Sugar: 15.2 per cent. Purity: 84.3 per cent.

Plot 3. Yield: 9.9 tons per acre. Sugar: 14.22 per cent. Purity: 79.5 per cent.

Plot 4. Yield: 9.9 tons per acre. Sugar: 13.0 per cent. Purity: 76.0 per cent.

In 1892 the plots were 1-100 and ¼ acre each, four of the sixteen plots being ¼ acre in area. The yields from the ¼ acre plots were 18.7 tons, 20.5 tons, 25.0 tons, and 25.7 tons per acre, and the sugar percentage 15.18, 16.7, 15.9, and 18.9. The coefficient of purity was between 82 and 85. The yield from the 1-100 acre plots was somewhat higher, as was to be expected, the sugar content ranging from 13 to 15.8 per cent., and the coefficient of purity from 76 to 85.

The plan of culture adopted as the result of the three years' study is as follows: After land had been plowed, harrowed, and made quite smooth, even, and free from lumps, stones, or trash, seed was sown with an ordinary hand drill, sowing eighteen pounds to the acre, covering an inch or less in depth, in double rows one foot apart, separated by a space two feet wide. Then, with one horse and a shovel plow, a trench was made in this space, the dirt being thrown on both sides to finish covering the seed. The rows are worked over quickly with a rake or hoe, and the seeding is complete. Beet seed requires considerable moisture to produce germination, hence, in a dry spring, water may be turned in these ditches and beets brought forward, independent of dry weather.

To facilitate irrigation, rows should not be more than three hundred feet in length, preferably less. It should not be necessary to drench the upper end in order to moisten the lower end.

Proper cultivation consists in hand hoeing or working with a fine-toothed cultivator, the surface of the ground being stirred as soon after irrigation as practicable. From experience at this Station it seems safe to state that the more careful cultivation, with the proper amount of water when needed, the more sugar per acre.

Bulletin No. 36 discusses the general outlook for the sugar industry in Colorado. The question of market for the sugar which might be produced in the State is answered as follows: "To produce the sugar consumed by the inhabitants of Colorado would require five factories of large size, employing two hundred men each, who, with their families, would represent about four thousand people. It would require the growing of sugar beets on fifteen thousand acres of land, and add more than three hundred dollars to the income of each of two thousand farms."

Touching the question of profit, the writer says: *"If prices are such as to make the business profitable anywhere, then it will pay in Colorado."*

The irrigable portions of Colorado below 5,000 feet in altitude and east of the Rocky Mountains, possess the best possible climate for the growth of sugar beets, as do many of the valleys of the western portion of the State, but the parks of Colorado are too cold for the sugar beet to be grown with profit.

The common cause of failure among beginners is a lack of thorough preparation of the soil. The plowing should be done in the fall, subsoiling to fifteen or eighteen inches. If this is done, a thorough harrowing just before planting will be all that is needed.

If the plowing is done in the spring it should be delayed until just before planting. The planting is done with a drill. An ordinary wheat drill may be used, but there are special drills for planting beets. Twenty-four inches is recommended as the distance between rows, being none too far apart for irrigation.

The quantity of seed recommended to be sown is at the rate of twenty pounds to the acre. This quantity is large, but advisable in order to get a full stand. The seed should be put in about an inch and a half deep. If the ground is thoroughly wet at the time of planting half an inch may suffice. If the plowing is done in the spring it may be advisable to irrigate the ground thoroughly before plowing, and thus insure a good supply of moisture in the subsoil.

If, after the seed is sown, the weather is so dry that the seed has to be "irrigated up," the chances of a profitable crop are slight. The seed can be successfully "irrigated up" by running a furrow six inches from the drill and allowing a small head of water to run until it has wet the seed by soaking sideways.

The planting may be done from the last of March till the middle of June. Sugar beets sown the first of May will be ready for harvesting about the first of October.

The first cultivation should take place as soon as the plants are up enough to enable one to follow the row. Whatever implement is used, it should merely scratch the surface of the ground, leaving it level and killing the small weeds without throwing dirt onto the young plants. The weeds must be kept down. The ground should be cultivated after each irrigation to level the ground and make a dirt mulch on top to preserve the moisture.

The beet crop in Colorado will need one, and possibly two or three, irrigations. The last irrigation should be given about six weeks before the crop is mature.* In 1895 a heavy rain in September kept the beet crop in full growth until frost, and produced a crop with much less than the usual amount of sugar.

The plants should be thinned when they have four leaves, leaving but one plant in a place. The distance between plants should be eight to ten inches. There is generally but little difference in the weight of the crop in cases where the beets stand six, eight, and ten inches apart. It is easy to grow beets weighing five pounds each, where the soil is rich, by thinning to twelve inches, but such beets are inferior to beets averaging less than two pounds for sugar, and also for stock feeding.

In thinning, the plants are cut out by means of a sharp hoe, leaving bunches of a few plants each, which must be thinned to a single plant by hand.

The soil of Colorado is generally rich enough to grow several crops of beets without fertilizing, but it must eventually be fertilized in order to maintain the yield.

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*** This is a general statement, and must be deviated from in special cases.—H**

In case alfalfa ground is broken up beets should not be grown on it the first season, but rather a crop of wheat. This will put the soil in better condition and will rot the alfalfa roots. It is not advisable to grow beets more than two years in succession on the same ground.† Alkali ground may be an exception.

If barnyard manure is used to fertilize the soil, the beets can advantageously follow a crop of corn.

The best varieties are the Kleinwanzlebener and Vilmorin.

The harvesting is done either by means of a beet puller or by plowing a furrow near the beets and pulling them by hand.

The topping is done by means of a heavy knife. Topping machines have, as yet, not been successful.

The factories work on beets hauled directly from the field up to the time freezing weather sets in. Beets to be used in the later part of the season should be protected from freezing; for this purpose they may be put into shallow pits and covered with straw and dirt, either near the factory in pits provided by them, or in the field.

The cost of growing an acre of beets varies in different parts of the country, the size of area planted, the condition of the ground, etc. The range is from thirty to forty-five dollars, or from two to four dollars per ton.

About eleven tons of sugar beets per acre at four and a half dollars per ton is a fair average crop, with a possibility of a much larger yield. Compared with alfalfa or wheat, the return seems large, but much more labor is required to produce it.

Sugar beets have a high value for stock feeding. They have been fed at the College with good results, except where fed to steers. The beets seem to be too watery for profitable feeding to steers where the feeding is done out of doors in cold weather. It is advisable not to feed them to fattening lambs for the last six weeks before marketing, grain being preferable at this period, so that the flesh and fat may harden for shipment.*

The tops are good feed for all classes of farm animals. They may be fed at once, as soon as harvested, or put in a silo and fed through the winter.

The next record of results occurs in bulletin No. 42. In 1897 we made an effort to enlist persons in different parts of the State in the raising of sugar beets. The Station has already established beyond any doubt the adaptability of both the soil and climate of this section of the State to the cultivation of the sugar beet, and also of that of the Arkansas valley, where the substation at Rockyford is located, but no co-operative work, including all sections of the State, had been entered upon. The Station received from the Department of Agriculture at Washington, five hundred pounds of beet seed, and from A. Keilholz, Quedlinburg, Germany, two hundred pounds. This seed was sent to six hundred and eleven persons residing in in forty-seven counties of the State. Most of the analyses of these beets were made by the Department of Agriculture in Washington. The State was divided into five sections, as follows:

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† Without fertilization.

* The author does not make any statement as to the extent to which grain should replace the beets at this period, whether wholly or only partially.—H.

1. The valley of the South Platte and its tributaries.
2. The Divide south of Denver, where crops are raised without irrigation.
3. The valley of the Arkansas.
4. The valley of the Grand.
5. The San Luis valley.

The varieties used were the Kleinwanzlebener, Vilmorin, and the Imperial White. As there were one hundred and six samples of the Kleinwanzlebener variety out of the one hundred and twenty-five recorded, no distinction is made between the varieties in this summary.

The percentage of sugar in the samples from the Platte valley ranged from 11.5 to 20.0, the coefficient of purity from 73 to 86, and the crop in tons from 9 to 47.

The percentage of sugar in the samples from the Divide section, grown without irrigation, ranged from 11 to 18, the coefficient of purity ranged from 71 to 87, and the yield in tons from 9 to 22.

The percentage of sugar in the samples from the Arkansas valley ranged from 12 to 20, coefficient of purity from 73 to 86, and the crop in tons from 12 to 40.

The samples from the Grand valley showed percentages of sugar ranging from 12 to 19, coefficients of purity ranging from 74 to 86, and crops from 15 to 42 tons.

The samples from the San Luis valley * showed percentages of sugar ranging from 11.5 to 17.9, coefficients of purity from 74.2 to 86.9.

The time of ripening of beets in Colorado will vary, of course, but the average of the samples taken between September 25th and October 10th is 14.1 per cent. sugar and 80.7 per cent. purity, which is an excellent grade of beet. To get the crop to ripen is the principal aim of the beet grower. The most important factor in this is

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* Altitude 7546 feet.

that the beet shall be kept growing all the time from the sprouting of the seed until the harvest. Some of the conditions on which the ripening of the crop depends are beyond the control of the grower. In Colorado it is true in general that the crop will not ripen until the vigor of growth has been checked by frost. The best means of determining whether a crop is ripe or not, that is, in condition to go to the factory, is by means of an analysis, but a good judgment can be formed by cutting a beet and noticing the rate at which the cut surfaces darken.

The increase in percentage of sugar and coefficient of purity during ripening is about three per cent. for the former and about five per cent. for the latter.

Some very suggestive facts relative to methods of culture were observed during this year's study. Certain principles of beet growing have come to be considered as essential to the production of the best beets. These principles were violated by most of the growers of beets this year, it being their first experience, and yet they obtained good results. It is said that beets should never be planted on new ground. This was violated with good results, giving, in one case, beets of 15.2 per cent. sugar and 82.4 per cent. purity, and in another 19.4 per cent. sugar, and in others the beets were above the average. Ground which had been broken but one year gave uniformly good results. So, too, in regard to time of plowing and subsoiling. All writers on sugar beet culture agree that beets should not be planted on ground that has been recently manured. Sixteen persons report manuring with stable manure. The crops were late in ripening, but with three exceptions, the quality was good. The results as a whole indicate much more gain than loss from the application of stable manure.

The hardest part of beet raising is to get a full stand all over the field. The poor growth of the seed is due to lack of moisture, too deep planting, and poorly prepared ground. The lack of moisture can be overcome in two ways—by irrigating before or after planting the seed. The latter seems to be more promising as a general method. Of fifteen persons trying this method, eight report having obtained a thick stand, being twice as large in proportion as those reporting a thick stand by depending on rain or the original moisture in the ground.

Mr. Geo. H. West, of Greeley, contributed an interesting article, published in bulletin No. 42, containing the observations and conclusions of his study of the subject, which he designates "Growing Sugar Beets for Factories." Mr. West studied this subject in Nebraska, Utah, and New Mexico. Of the growing of beets in Nebraska he says: The farmers are largely Germans, with some Russians. Women and children work with the men in the fields. Where a large acreage is in beets, the thinning, weeding, hoeing, pulling, and topping is done by contract. Laborers receive from fifteen to twenty dollars per month, the usual wages by the day being one dollar and board. On contract work the rate is from fifty cents to one dollar for boys; one dollar for men and women, without board. For a man and team, two dollars and fifty cents per day; for man and horse, one dollar and seventy-five cents. Land rent from three dollars and fifty cents to six dollars per acre.

The average yield in 1897 was 7.25 tons, and the sugar extracted by the factory at Norfolk was 10.95 per cent. The percentage of sugar in the beets was 13.1 per cent., purity 81.5 per cent.

The Grand Island beet raisers averaged 8.1 tons per acre. The average percentage of sugar in the beets in 1897 is said to have been 12.87, and purity 79.5. The percentage of sugar obtained from these beets by the factory was 8.72.

The tables given show that in 1897 the factories at Norfolk and Grand Island treated the largest tonnage and made the highest saving attained up to that year. The range of farm wages is from fourteen to twenty dollars per month, with board; and from one dollar to a dollar and a quarter by the day. Women and children generally work on the contract plan. Many girls get a dollar a day in the beet fields, and prefer it to house work. Boys from ten to eighteen years of age receive from fifty to eighty cents per day, a man and team two dollars and fifty cents, and a man and horse one dollar and seventy-five cents per day. Contracts can occasionally be made, as in Colorado, at two dollars per day for man and team. Land rentals range from four dollars to seven dollars per acre. The crop of 1897 is said to have been reduced fully one-third by drought. No beets are grown by irrigation in Nebraska.

At Lehi, Utah, the conditions are said to be ideal for the growing of beets and running a sugar factory. The farms vary from five to forty acres in extent, and fully nine-tenths of them are worked by the owners. Mortgages are rare and the farmers prosperous. The women do not work in the fields, and the girls seldom work there unless at home. Much of the hand labor is done by boys. The average acreage per grower is less than four acres. The highest average yield per acre was in 1896, 13.5 tons. The average per acre from 1891 to 1897, inclusive, was 9.44 tons. The highest average percentage of sugar in the beets was, in 1896, 13.9 per cent. The average percentage from 1891 to 1897, inclusive, was 12.4 per cent. The average percentage of sugar extracted, 1891 to 1897 inclusive, was 8.46. Land rentals range from $7.50 to $15.00. The soil shows a great diversity about Lehi, but is generally a heavier soil than the uplands of northern Colorado.

The Eddy, New Mexico, sugar beet factory has been run for two seasons only, 1896 and 1897. The valley, though a natural fruit garden, lacks the farming population, and perhaps, too, the close, careful cultivation and knowledge of irrigation of the older farm districts of Colorado. In 1897 they grew 1,900 acres of beets; yield, three tons per acre; percentage of sugar, 14.2; purity, 80 per cent.; percentage of sugar extracted from the beets, 10.53.

The average cost of growing and delivering a crop of beets at Norfolk, Nebraska, is $26.50 per acre; the average profit, $11.04. The yields range from five to fifteen tons per acre. The net returns vary from a profit of $29.00 to a loss of $7.55 per acre. At Grand Island, Nebraska, the average was $28.73 per acre, and the average profit $9.27. The yield varied from five to twelve tons per acre, and the net results from a profit of $17.00 to a loss of $12.00 per acre. Mr. West puts the average cost of growing and marketing sugar beets in Nebraska at $30.00 per acre, and states that the officials of both factories put it at the value of seven tons of beets, or $28.00.

The average cost of growing beets in Utah, not including land rentals, is put at $32.50 per acre. The average yield is stated at 10.1 tons, but the yield for 1897 was 6.75 tons. Improved beet cultivating implements had not, at that time, been introduced into Utah, and this, with the higher land rental and cost of irrigation, raises the actual cost to probably $40.00 per acre.

Relative to the profits of beet culture, Mr. West says: Large yields are regularly obtained by those farmers who do thorough, clean work, and intimates that therein lies a big secret of success.

It is also pointed out that the labor question is a most serious problem in this industry. It is too important to be entirely passed over, even in a summary such as this.

Concerning the feeding of pulp to cattle and sheep he gives results obtained in Nebraska and Utah. At Lehi the pulp is placed in silos with addition of about one-half per cent. of its weight of salt. The cattle always have access to plenty of hay, pulp, and water. *They never feed a pound of grain in fattening the stock*, unless the pulp gives out.

John Reimers, Grand Island, Nebraska, had had three years' experience in feeding pulp to cattle. He fed fifty pounds of pulp, twenty pounds of corn meal, a little bran, and oil cake, and the usual amount of hay per day, as a full ration. Hake Bros., also of Grand Island, fed lambs a mixture of four pounds of pulp to one or one and a half pounds of corn meal, besides hay, as a full ration.

The results are highly satisfactory. The pulp is said by Superintendent Geo. Austin, of Lehi, to give the best results after fermenting in the silos for thirty days, and should not be fed sooner than this.

The experiments made in 1898 are grouped as follows in bulletin No. 51:

1. *Different dates of planting.* Results in favor of early planting in respect to yield, sugar content, and purity.

2. *Planting on freshly plowed ground as compared with planting on ground plowed a few days before planting.* Resulted in favor of planting on freshly plowed ground by 2.3 tons in yield, two per cent. in purity, and a slight excess in sugar.

3. *Seed irrigated at planting as compared with that not irrigated.* Results obtained on the College Farm showed no advantage from this practice. The soil was a rather heavy loam and was moist at planting time. Good results have been observed from this practice on lighter soils.

4. *Soaking seed before planting.* Results did not show any gain from the soaking of the seed.

5. *Sowing at the bottom of a three-inch furrow.* The resulting stand was not so good as that obtained by sowing at ordinary depths. The yield was once as good and twice poorer than that from similar rows of ordinary planting. The percentage of sugar and purity were not perceptibly different from other plantings.

6. *Different depths of planting.* The depths at which the seed was planted were from one-half an inch to an inch and a half. The first series, planted May 11th in a wet soil, showed no difference, but the later planting, made May 27th when the soil had dried out considerably, showed an advantage in favor of the deepest planting, amounting in comparison with the shallower plantings to more than one-third of the crop. The stand, yield, and quality were all better than in the cases of shallower planting.

7. *Transplanting.* Transplanted beets are usually ill-shaped. The yield may be good, percentage of sugar and purity high, but the method would not be a financial success.

8. *Different distances of thinning.* The results obtained show that the distance apart of the beets, from four to ten inches, has but slight influence on the quality of the crop as to sugar and purity. In a general way the thicker stand tends to a larger yield, but there are exceptions to this statement.

9. *Different dates of thinning.* The results show that the

thinning of beets can be extended over a period of two weeks without injury to the crop.

10. *Variety tests.* Six varieties, Zehringen; Vilmorin's Improved, grown in Russia; Kleinwanzlebener, grown by Vilmorin; Pitschke's Elite; Vilmorin's French, very rich; and Schreiber's Elite were grown side by side with Kleinwanzlebener, strain not given, with almost identical results in percentage of sugar and purity, the sugar ranging from 15 to 17.20 per cent., and the purity from 76 to 81.9. The average of all the samples analyzed in this test is 16.04 per cent. sugar, and 78.9 purity.

11. *Number of irrigations.* At Rockyford, beets were grown without irrigation, with one, and with four irrigations. This experiment was of little value, being defeated by the unusually heavy rains of that season.

At Pueblo, Mr. C. K. McHarg applied water to one-half of some experimental plots twice after the 20th of August, the other half receiving none after that date. The two later irrigations produced an increase of one-seventh in the weight of the crop, and the percentage of sugar was increased; beets from the half irrigated late, contained 16.42 per cent. sugar, 81.0 purity, and those from the other half contained 15.79 per cent. sugar, 81.7 purity.

12. *American grown seed vs. imported seed.* Two samples of American grown seed were used, one grown in Utah and the other in New Mexico, both were strains of Kleinwanzlebener beets. The imported seeds were the Original Kleinwanzlebener, Vilmorin, Mangold, and Elite Kleinwanzlebener.

The Elite Kleinwanzlebener and the Vilmorin were sent us by the U. S. Department of Agriculture as the best beet seed that they could get. The Original Kleinwanzlebener was selected by the Utah Sugar Company as, in their judgment, the best brand of seed on the market from which to raise their own seed. The Utah grown seed produced as large a crop and one richer in sugar and purity than the average of these three. It excels its parent strain in richness and purity, and is but little inferior in quality of crop.

The New Mexico seed equals the Vilmorin and is not far behind the original Kleinwanzlebener.

The germinating quality of the seed is quite satisfactory.

In 1899 the questions whose solution were attempted were:

*Does it pay to subsoil?* The results of ten tests made at this Station show an average gain of 18 per cent. in the weight of the crop as the result of subsoiling.

*Is it advisable to plant the beet seed very early?* The average crop from ten plots sown between April 10th and 20th was 27.7 tons; from ten plots sown between May 1st and 10th was 24.3 tons; from ten plots sown between May 15th and 26th was 20.4 tons; and from ten plots sown between May 31st and June 10th was 15.3.

The percentage of sugar in these various crops scarcely differed at all, 0.76 of one per cent. being the maximum difference, and 3.2 was the maximum difference in purity. The difference in crop, however, is very decidedly in favor of very early planting.

The question of the distance between rows is recurred to again, and a former recommendation is repeated, *i. e.*, making the alternate spaces between rows narrower and wider. The distances advocated are eleven and twenty-seven inches. The chief advantage claimed is in irrigating, also an increase of crop.

### IRRIGATING UP THE SEED.

Twelve experiments were made with irrigating up the seed, and a like number without irrigation. Of the twelve experiments with irrigation none failed, of those without irrigation two failed. The crops from the twelve irrigated at the time of planting averaged 26.3 tons to the acre. The crops from the ten plots which came up, but which were not irrigated at the time of planting, averaged 25.4 tons to the acre.

### INSECTS INJURIOUS TO BEETS.

The earliest observations on this subject seem to have been made by Prof. C. P. Gillette in 1894, when he records the leaf hoppers *Gnathodus abdominalis*, *Platymetopius acutus*, and *Agallia uhleri*, as doing injury to beets in the vicinity of Grand Junction, also a mealy bug, *Dactylopius solani*, as infesting the crowns of the plant. The next mention of injury to beets by insects is in 1897, when the writer's patch of beets was seriously injured by the leaf hoppers *Agallia uhleri*, *A. sanguineolenta*, *A. cinerea*, and the striped beetle *Systena taeniata*. Later *Monoxia puncticollis*, and also the blister beetle, *Macrobases unicolor*, did some damage.

In 1899 the beet army-worm (*Laphygma flavimaculata*) made its appearance near Grand Junction, and was very destructive. It did not appear in injurious numbers in this locality in 1900. Prof. Gillette and his assistant, Mr. E. D. Ball, found but few specimens of either the first or second brood. Prof. Gillette (Thirteenth Annual Report of the Colorado Agricultural Experiment Station) says of this failure of the insect to appear the second season: The very sudden appearance of this insect, which had never before been considered injurious, in such destructive numbers, and its equally sudden disappearance, is quite remarkable. Particularly is this so from the fact that the fall brood of worms in 1899 were but little parasitized, and the moths matured in enormous numbers. The latter must have failed, for some reason, to winter over. These worms appeared on some experimental patches of beets at Lamar and Rockyford in 1899, and the first brood appeared in destructive numbers in 1900. The worms began to appear during the first week in June, and were abundant by the 14th, when spraying was begun. Late planted beets were not injured by them, except where they were planted near patches of weeds or earlier beets. The poisons were effectual, especially where two sprayings were made with Paris green.

Other insects mentioned by Prof. Gillette as having been observed on beets and not already mentioned, are *Nysius angustatus* (often called false cinch bug), more or less abundant everywhere, in some cases causing beets to wilt and die. *Deilephila lineata* was found as an occasional feeder, especially where purslane was allowed to grow. (Mr. Ball's notes.)

## Chemical Considerations, Bulletin No. 46.

### THE EFFECTS OF ALKALI.

Sodic carbonate, or black alkali, when present in quantities equal to less than 0.1 per cent. of the weight of the dry soil, does not prevent a satisfactory germination, but a still smaller quantity, as little as 0.05 per cent. of the weight of the dry soil, will corrode the plants, both plumule and radical, causing their death. We have occasionally observed corroded plants in alkali ground, but in spots only. The ground experimented with was very strongly alkalized, the worst, in fact, that we had at our disposal.

Sodic sulfate, or white alkali, does not prevent germination when present in quantities equal to less than 0.70 per cent. of the weight of the dry soil. No corroding by this salt has been observed.

The effect of the black alkali, sodic carbonate, is not mitigated by the presence of the white alkali. The sodic salts hasten germination by 36 to 48 hours.

Magnesic sulfate, one of the constituents of our alkalies, retards but does not prevent germination.

The beet plant can endure a larger amount of white alkali in the soil after it has become established.

Alkalinity of soil did not effect date of ripening in a series of experiments made at the Station.

Alkali does not affect the sugar content of beets grown on soil in good, or even fair tilth.

The ripening of beets may be seriously affected by a rainfall, or untimely irrigation. The crop of 1897 showed this plainly. On September 8th the beets had already begun to ripen, from the 10th to the 14th, 0.74 inches of rain fell; on September 22nd the samples analyzed showed a lowering in the percentage of sugar present. This loss was not regained for nearly three weeks, the beets, however, increased greatly in size during this time.

The ripening in this case took place more suddenly than is probably usual, and corresponded to an increase of from 2 to 3.5 per cent. in the different plots and is equivalent to about one-third of the total yield of sugar—that is, if the yield of sugar be 6,000 pounds per acre, 2,000 pounds is formed during the period of ripening.

Beets were covered with straw and left undug until January 7, 1898, with a slight gain in percentage of sugar and purity, showing that beets under favorable conditions may remain unharvested without loss of sugar or weight of crop.

Distribution of the sugar in the beets. In bulletin No. 11, it is stated that the amount of sugar increases in the successive sections of a beet from the top downward. This is not sustained by bulletin 42, which shows that the upper third, including the crown, contains only about 0.2 of one per cent. less sugar than the lower two-thirds, and these, the lower two-thirds, cannot be said to differ at all; sometimes the second and sometimes the third third having the higher percentage of sugar, the difference always being so small that it is insignificant.

### SUGAR IN THE CROWNS.

The crown as used in bulletin No. 42, is really a structural portion of the beet, and not any indefinite portion which may have chanced to grow above the ground. It is very rarely the case that sugar beets, Kleinwanzlebener or Vilmorin, grow above ground at all with us. The difference between the sugar content of the crown and the beet from which it is cut is about one per cent. The coefficient of purity is lower than that of the beet, but not necessarily poor. The example given shows beets 16.1 per cent. sugar, 88.0 purity; crowns 15.1 per cent. sugar, 82.4 purity.

### EFFECT OF FREEZING ON BEETS.

Simple freezing does not cause any change in the sugar. If thawing can be prevented the crop is not necessarily lost if frozen.

### DRYING OUT OF BEETS.

This takes place rapidly if the beets are exposed. Beets wrapped in paper and placed on the earth of a cellar bottom lost about five per cent. of their weight during the first twenty-four hours; from this the daily loss fell to about two per cent., at which rate the beets continued to lose up to the seventeenth day. The percentage of sugar increased.

The drying out of beets has another effect, it is accompanied by a loss of sugar. This loss varied in the experiments recorded from one-fortieth to one-sixth of the sugar present.

The suggestion is made that the loss may be materially influenced by the condition of the crop, the loss being greater in unripe beets than in riper ones.

The yields recorded range from 7.9 to 11.8 tons per acre for sugar beets, and 15.9 tons per acre for Lane's Imperial.

The ratio of the weight of the tops to that of the beets was found in two ways. First, weighing the carefully removed tops and beets gave for sugar beets of different varieties ratios varying from 1:1.087 to 1:1.274, or the weight of the tops varied from 78.5 per cent. to 92.0 per cent. of the weight of the beets. The second method was to weigh the beets as harvested and the tops as removed from them. On removing these tops no part of the crown of the beet was taken. The result was that we found the ratio to be 1:1.14. The general ratio obtained by the first method was 1:1.12. The weight of leaves as harvested in the field equalled 87.7 per cent. of the weight of the roots. The results obtained in the laboratory gave their weight as equal to 89 per cent. of that of the beets.

The tops of beets grown on alkalized ground were relatively a little heavier than in cases where the ground was practically free from alkali.

The tops increase but little in weight during the last six weeks of the growing season. The beets, on the other hand, gained 64 per cent. of their weight at the beginning of this period.

The beets ripened this season, 1897, the second week in October, and about one third of the total crop of sugar was deposited during this period.

The percentage of dry matter in sugar beets increases with the maturing of the beet. In green beets harvested September 2nd we found from 8.8 to 14.6 per cent., with an average of 12.1 per cent. In mature beets it ranges from 17.0 to 20.5 per cent., and in exceptionally favorable seasons it may be higher. Sugar forms a larger percentage of this dry matter in mature beets than in green or immature beets.

There is a little more dry matter in the top one third of the beet than in the other two thirds.

Stock beets contain less dry matter than sugar beets. We found the dry matter ranging from 12.25 to 14.63 per cent. in mature beets.

The marc or pulp, the portion left after the sugar and soluble matters have been washed out, ranged from 4.21 to 5.25 per cent. The average is about five per cent.

For fodder analyses of sugar beets grown on alkali soil and soil free from alkali, of stock beets, beet tops, and marc or pulp, see bulletin No. 46, page 37.

Alkali in the soil tends to increase the percentages of ash and albuminoids.

The feeding value of dry pulp may safely be estimated as equal, pound for pound, to the dry sugar beet.

One ton of sugar beets yields about four hundred pounds of dry matter, and only one hundred pounds of dry pulp. One ton of stock beets yields about two hundred and forty pounds of dry matter, which is richer in albuminoids and nitrogen-free extract than the pulp is; the pulp, however, is a by-product and the stock beets are not.

The percentage of crude fiber in beets is quite irregular, but uniformly higher in beets from alkalized ground than others.

Alkali affects the composition of the beets more than that of the leaves.

The percentage of ash in the beet ranged from 0.79 to 1.33 per cent. in immature beets, samples harvested September 2nd, to from 0.95 to 1.39 per cent. in mature beets harvested October 13th. The average is 1.10 per cent. of ash in the fresh beet.

Fifty-eight per cent. of the total ash constituents removed from the soil by the roots, and 70 per cent. of all the mineral constituents removed by the leaves, had been gathered by September 2nd. The accumulation of ash constituents continues until the period of ripening.

The slight decrease in the percentage of ash as the roots approach maturity is due to the rapid increase in the weight of the beets. There is no diminution in the amount of ash constituents in the crop.

The influence of alkali, present in large quantities, is to increase the ash by about two per cent., reckoned on the dry matter.

The ash is quite evenly distributed throughout the beet, with a slightly larger amount in the top one-third, but the percentage of ash is higher in the dry matter of the bottom third.

The ash of the beet has a pretty uniform composition, generally showing about 3.5 per cent. sulfuric acid, 7 to 9 (usually about 8.5) per cent. phosphoric acid, 48 to 52 per cent. of alkalies, 2 to 3 per cent. of lime, about 6 per cent. of magnesia, 11.5 to 14.5 per cent. of chlorin, and about 15 per cent. of carbonic acid in the fine ash. When the carbonic acid is higher than 15 per cent. either the phosphoric acid or the chlorin is correspondingly lowered.

The composition of the ash of the leaves is quite different from the composition of the ash of the roots. The ash of the leaves contains from 3.5 to 3.9 per cent. of sulfuric acid, 1.8 to 2.3 per cent. of phosphoric acid, 23.7 to 25.7 per cent. of potash, 22.3 to 25.5 per cent. of soda, 1.5 to 2.5 per cent. of lime, 6 per cent. of magnesia, 23.3 to 28.5 per cent. of chlorin, and from 10.6 to 15.0 per cent. of carbonic acid.

The composition of the ash of immature beets is the same as that of mature beets. The only exception to this statement seems to be the percentage of chlorin in the ash of the leaves, which increases so generally and uniformly that it suggests a relation between the degree of maturity and the quantity of chlorin.

The soil, repeatedly referred to as alkalized, contained chlorid of sodium, or salt, equal to 0.025 per cent. of the weight of the air dried soil. This gives us 2,800 pounds of salt in each acre of soil, taken to a depth of two feet. The total water soluble in this soil varies from 0.09 to 1.4 per cent. of the weight of the air dried soil, taken also to a depth of two feet. The higher figure gives us the immense quantity of 49.0 tons of alkali per acre, consisting of 16.33 tons of sodic sulfate, 17.64 tons calcic sulfate, 10.27 tons of magnesic sulfate, and 1.25 tons of ordinary salt.

Continued cropping to beets would soon show a perceptible reduction in this quantity of sodic chlorid, especially if the leaves were carefully removed, but the ground water is rich in salts, and is capable of replacing this, as well as the other "alkali" salts removed.

Stock beets, including leaves, remove, crop for crop, more soda salts than sugar beets do, but not ton for ton.

The chemical work of 1898 and 1899 is recorded in bulletin No. 58, which continues the study of the effect of soil conditions on the stand and quality of the beets, and the chemistry of the beet itself.

There were certain spots in which the seed failed to germinate, and the cause of this was not discovered. It was not explained by either a lack or an excess of moisture, nor was the alkali as excessive as in some other places.

The plot experimented with was the same as that used in 1897, the results of which appear in bulletin No. 42.

The rainfall for the months of July, August, September and October was 2.8 inches, the total amount received by the crop from the time of planting till harvested was about eight inches. The ground at the time of planting was wet, and the water plane was about two feet below the surface. The water fell about a foot in the next thirty days. An irrigation given July 8th to 11th did not suffice to raise the water to its earlier level, and it fell two feet in eleven days. The level of the ground water was not sensibly affected two hundred feet east of my plot by this irrigation. The water plane fell slowly from July 25th until early in October, when it reached its lowest point. The water plane from July 15th to October 10th ranged from three to four and one half feet below the surface at the east end of the plot, and there were but few beets in this section. At the upper and higher end of the plot the plane varied from 5.2 to 6 feet below, and the crop was excellent. In an intermediate section the water plane varied from 3.5 to 4.5 feet below the surface, with an abundance of alkali, and it yielded a good crop. The crop showed the need of water during the later part of the season, notwithstanding the high water plane. The ground had been kept as mellow as possible, and clean, having received five hoeings and five cultivatings. This plot of ground was put in beets in 1899, and needed no irrigating, it having been sub-irrigated this season from higher ground lying to the west of it. The wetness of the ground interfered with the cultivation of the crop, but the mechanical condition of the soil was so much improved over that of previous years that the cultivation was much easier. In 1899 this plot was soaked, August 31st to September 2nd, and the crop left to itself. The crop from this plot in 1897 was, taking an average of all varieties of sugar beets, about nine tons; in 1898, thirteen tons; in 1899, fourteen and one half tons to the acre. The increase in the crop is due to the betterment in the condition of the soil and a rather better stand.

Application of manure, sheep manure in this case, improved the stand by at least ten per cent.

The ripening of the crop of 1898 was entirely different from that of the crop of 1897. In 1897 there was a rainfall in September, on the 14th, which interrupted the ripening. In 1898 the crop developed continuously up to maturing. No sudden increase in the percentage of sugar was observed as in the preceding year, when the increase was from 2 to 3.5 per cent. In 1898 the greatest gain observed, which could be attributed to ripening, was 1.4 per cent. The varieties grown by the Farm Department remained almost constant from October 3rd till October 22nd, in only one variety was there a gain of as much as one per cent. The ripening of the crop is much more gradual some seasons than others. The same observations were made in regard to the effect of the alkali upon the quantity of sugar, coefficient of purity, and time of maturing as were recorded in bulletin No. 46, namely, that the effect of the alkali is not detrimental.

The effect of the manure upon the sugar content and coefficient of purity, considering all of the tests, which, however, are not concordant with one another, is to lower both the sugar content by from 0.5 to 1.2 per cent. and the coefficient of purity by from 0.1 to 3.1 per cent.

The effect of the manure on the shape of the beet was bad, and this effect was uniform in the six comparative experiments which were conducted.

These effects of the manure were noticeable the second year after its application, but not in so marked a degree as they were the first year.

The result the second year is probably due to the failure of the manure to thoroughly rot and become incorporated with the soil.

Cut straw was also used as a dressing. Its effects were beneficial to the soil, but less in degree than those of the manure. Its effects upon the beets were not pronounced enough to permit the expression of a positive judgment. The results of this experiment are taken as corroborative of the opinion expressed elsewhere, that it is the mechanical condition of our alkali soils that preeminently needs improvement. That section of the plot which has been in the worst mechanical condition shows more alkali on the surface than the others. The water soluble in the soil, however, is greater in other portions of the plot. No attempt is made to formulate the relation existing between the mechanical condition of the soil and the amount of alkali present. These two factors are spoken of together as producing certain effects on the crop, but the opinion is expressed that the alkali, *per se*, is not the cause of these effects. This opinion is based upon the observation of spots where there is an abundance of alkali, but where the mechanical condition of the soil is better. No statement is made as to the extent of the influence of the alkali upon the mechanical condition of the soil. This point is left as an open question. The crops have improved each year, showing a mitigation of these conditions due to cultivation. This improvement is not due to drainage, for the water table has not been lowered and is seldom low enough to prevent capillarity from bringing moisture, and consequently salts, to the surface. An attempt was made to determine the direction and rate of the flow by introducing lithia salts into one of the wells, but it was found upon examination that the ground water contained lithia at all times.

The effect of seasonal differences upon the crop was noticed in the greater amount of dry matter in the beets in 1898 than in 1897. The difference in the percentage of dry matter attributable to the seasons was from 3.0 to 3.75 per cent., about one sixth of the total dry matter in the beets.

The question of the rate of drying out was taken up again with more care than in previous years, with about the same results, *i. e.*, that the loss for the first twenty-four hours was about five per cent. In this case, with a temperature of 57 to 66 degrees, the loss was 4.39 per cent. It fell to two per cent. in a few days, and remained at this figure for twelve days. The effect of drying out is shown in its effect on the average sugar percentage in 1898. In this year we analyzed 813 samples. The average percentage of sugar is found to be 15.12, without making any allowance for the drying out. We succeeded in obtaining fairly reliable data in 336 instances on which to base the deduction which should be made, and find it to be 1.5 per cent., which gives us an average of 13.62 per cent. for the crop.

The conclusions arrived at, as the result of many experiments to determine the relation existing between the size of the beets and their sugar content, are: That beets to be compared must be grown under the same conditions; that the conditions determining the percentage of sugar are so complex that no given weight can be accepted as a limit which, if exceeded, will indicate that the beet is not of proper richness and quality for the manufacture of sugar; that when the large size is due to an excessive supply of plant food, or an unduly large feeding ground and a constant and very abundant water supply, the beet is quite certain to be low in sugar, but this will be true of all beets, large or small, grown under such conditions.

Eight experiments, in which beets weighing less than one half a pound are compared with beets weighing more than two pounds, showed that the smaller beets were richer in seven instances and poorer in one. The maximum difference in favor of the smaller beets is one per cent., the least difference is 0.19 per cent. The average difference is 0.50 per cent. The beets above one half pound in weight make the crop. The coefficient of purity is better in the larger beets, or at least as high as in the smaller ones. The conclusion drawn from another experiment is that too great a width between the rows tends to have the same effect as permitting beets to grow singly.

In 1898 it was observed that certain over-irrigated spots had turned yellow. Analysis showed that these beets were richer in sugar than the beets growing adjacent to them, but which had not been over-irrigated, by upwards of three per cent., and the coefficient of purity was much better, ten per cent. This clue was followed in 1899 with excellent results. The average percentage of sugar for beets grown by the Chemical Department in 1898 was 13.65. The average for all samples analyzed that season, 1898, was 13.62 per cent. The average for the season of 1899 was 14.69 per cent.* The effect upon the tonnage of the crop was not determined, but it was not materially affected in any observed case.

This is unlike the effects of a late and inopportune rainfall. The bad effects of this are probably due to the condition of the crop at the time of the rainfall, and not particularly to the amount of water that falls.

Cultivation and manuring increased the amount of phosphoric acid taken up, but did not increase the percentage of ash in the fresh beet. The greatest effect seems to have been on the percentage of chlorin, taken up, it having been lowered.

The percentages of phosphoric acid, lime and magnesia in the ashes of the samples of 1897 and 1898 were very nearly the same, but in 1899 the percentages of the two latter substances increased by one per cent. each.

The changes produced tend to bring the composition of the ashes more into harmony with the results of other observers, and indicate the tendency of cultivation and continued cropping to ameliorate the soil conditions and modify their effects upon the mineral matters taken up by the plants.

The effect of the manure was of two characters, mechanical and as a fertilizer.

The nitric acid in the ground waters was more variable and higher after than before the application of the manure.

The total solids were also higher during the season immediately following its application.

Heavy rains or an irrigation increase the amount of chlorin in the ground water. The increase was more pronounced and of longer duration after the manure was applied. The effects of the straw upon the soil lead the writer to attribute the effects of the manure principally to the organic matter in it, improving the mechanical condition of the soil and bettering its biological conditions, as indicated by the increased amount of nitric acid formed.

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* The average of all varieties, manured and not manured. The average for the not manured sections was 15.34 per cent.

Experiments made in 1897, 1898 and 1899 upon the effect of soaking beets in water at a temperature of about 42 degrees Fahrenheit for a period of seven days, resulted uniformly in showing an increase in the amount of sugar present, and also in the coefficient of purity.

The reducing power of beet pulp was determined by extracting the beets with 80 per cent. alcohol until the extract no longer reacted for sugar, then boiling with dilute hydrochloric acid and determining the reducing sugar thus formed and calculating it as pentose. The pentoses, or, as it is expressed in the bulletin, the reducing power, did not decrease as the beet matured. The rich beets showed higher percentages of pentoses than those showing lower percentages of sugar. The quantity of pentoses in stock beets is quite as great as that in sugar beets.

Soaking seemed to diminish the quantity of pentoses present.

The sugars present in the leaves of sugar beets in largest quantities are glucose and maltose. Cane sugar is present in small quantities only, or is entirely absent.

# CONCLUSIONS RELATIVE TO THE CULTURE OF SUGAR BEETS.

A rich, loamy soil is best adapted to the growing of sugar beets, but any soil that will produce good crops of grain will grow beets, and even soils too alkali to grow grains will grow beets.

Plowing is best done in the fall, subsoiling to fifteen or eighteen inches. Plowing may be done in the spring; in this case it is best to plow immediately before planting. In either case harrow quite smooth and even.

Results at this Station show a gain of 18 per cent. in weight of crop, in favor of subsoiling.

The time to plant will vary with locality and soil. Early planting gives largest crops. Good results have been obtained with plantings as late as June 13th at this Station, and June 15th at Rockyford, but four series of tests of ten experiments each, made in different sections of the State, show an average excess of 3.4 tons of beets for the plots planted from April 10th to 20th over similar plots planted from May 1st to 10th; 7.3 tons over those planted May 15th to 26th, and 12.4 tons over those planted between May 31st and June 10th.

If the soil is wet, very shallow planting will give good results, but the best results are generally obtained by planting from one inch to an inch and a half. Deeper planting is not advisable.

The distance between rows should be from 18 to 20 inches if in single rows. Mr. Watrous, in bulletin No. 21, recommends double rows 12 inches apart and 24 inches between rows. He claims that they are more easily irrigated. Prof. Cooke, in bulletin No. 57, recommends double rows 11 inches apart and 27 inches between rows.

Good crops have been raised by planting small quantities, three to five pounds of seed to the acre, but it is advisable to sow eighteen or twenty pounds to the acre. One of the most difficult things in beet growing in Colorado is to get a good stand.

In order to get a satisfactory germination of the seed, one or other of the following methods have given the best results: Either plant on freshly plowed soil with a good supply of moisture, or irrigate up.

Cultivation should begin as soon as the plants show the drills distinctly enough to be easily followed, when the surface should be thoroughly stirred to kill the young weeds. The young beet plants must not be covered.

Thinning may be begun as soon as the plants have gotten big enough, when they have four leaves, and may be extended over a period of two weeks. As the plants get larger, more care must be exercised on the part of the persons thinning, to avoid injury to the remaining plants.

The distance between the beets in the row may vary from six to ten inches —eight inches on an average gives a satisfactory crop. There is but little difference in the weight of the crop when the beets stand six, eight or ten inches apart. At twelve inches apart the beets are apt to attain an undesirably large size.

The cultivation of the crop must be varied according to the character of the soil. Any instrument, the plow, the cultivator or special beet cultivating implement, which will put the soil in good condition without covering or otherwise injuring the plant, may be used. During the growing season the beets should be cultivated as soon after an irrigation as is practicable, to prevent encrusting of the surface, to level the ground, and to make a mulch of fine earth.

The number of irrigations necessary to raise a good crop will vary with the seasons. Mr. Watrous, in bulletin No. 21, says that in ordinary seasons, with an average rainfall of 13.89 inches, one irrigation during the growing season is sufficient to produce the best results. Some experiments made at Rockyford under Prof. Cooke gave the same result. The rainfall of that season was unusually heavy. If the water is at the command of the grower, the beets should be irrigated often enough to keep them growing continuously from the beginning of the season until the time of harvesting. Under this condition it pays to irrigate until late in the season. The difference in the halves of six plots, one half receiving no water after August 20th and the other receiving two irrigations after this date, was one seventh of the crop, in favor of the later irrigation.

It would be difficult to designate the best variety. The various strains of Kleinwanzlebener and Vilmorin probably take precedence. The Lion Brand, Mangold and Zehringen have given excellent results.

The plots grown under the direction of this Station or on the College Farm have given large yields. The average for ten counties of the State in 1898 is given as 19.9 tons. In 1899 the averages for eight series of twelve plots each ranged from 15.3 tons to 27.7 tons per acre. The writer's experience and observation would lead him to put the average crop for this section of the State at from 10 to 14 tons, ranging from six to thirty tons per acre.

The average percentage of sugar in the beet will probably be not far from 13 per cent., taken for a series of years; the range in the different crops will be between 10 and 20 per cent.

The average coefficient of purity will be between 79 and 81; in very favorable years possibly 82, in unfavorable years 77 or 78.

The date of ripening will vary with time of planting, soil, season and treatment of the crop. The earliest harvesting of workable beets of which I have record for Larimer county is September 15th; sugar 14.71 per cent., purity 80.4.

Our experience with transplanting beets is that the beets produced are of very ill shape, but may be rich in sugar, and yield well.

The application of a liberal dressing of well rotted manure will lower the percentage of sugar and coefficient of purity a little, but the crop will be increased more than enough to compensate for this.

Beets should not be permitted to dry out after being dug, as there is a loss of sugar.

Freezing does not destroy the sugar in beets, but freezing and thawing injures the beets for sugar making.

The beet is a vigorous feeder. A crop of 14 tons of beets would remove 300 pounds of mineral matter, about one half of which, or 150 pounds, is potash, and 25 pounds is phosphoric acid. If the tops are taken off the field there will be a still larger quantity of these substances removed. The fertility of the soil may be maintained by the application of well rotted manure, and by a judicious rotation of crops.

The trimmings of the beets make good fodder for cattle. The fresh tops, however, are apt to have a laxative effect.

The dry matter in the beet pulp is of rather more value, pound for pound, than the dry matter from the fresh beet. The pulp as obtained from the silo contains 90 to 92 per cent. of water. Slight fermentation is said to improve it.

We have grown beets carrying as high as 19 per cent. of sugar in soil rich in "alkali" salts. The average percentages of sugar for the crops of 1898 and 1899, grown in such soil, were 13.65 and 15.34 respectively. The coefficients of purity were 84.6 and 80.8.

As a rule medium sized beets are richer than either small or large beets. By medium sized beets is meant such as weigh from one to two pounds. Large beets, beets weighing from two to four or even many more pounds, may be as rich in sugar and have as high a coefficient of purity as beets of one pound or less, if grown under the same conditions. If not grown under the same conditions they cannot be compared. Even big beets grown under different conditions cannot be compared. Two beets, weighing respectively 2.88 and 2.90 pounds, grown in the same plot of ground within two hundred feet of one another, but under different conditions in regard to water supply, showed 10.45 per cent. sugar, 67.0 per cent. purity, and 16.06 per cent. sugar and 85.1 purity. Big beets *may be* rich beets, the size alone is not determinative.

It has been stated that one irrigation may, under certain seasonal conditions, suffice to produce the best results in regard to crop and quality of beets. Under other conditions of the season or soil, or both, more irrigations will be necessary. The condition of the crop will determine how late in the season irrigation may be profitably practiced. If the crop has already begun to ripen either a rainfall or an irrigation which causes a second growth will prove detrimental, but if the crop is in such condition that a second growth is not produced a late irrigation may do good.

A late over-irrigation ofter does good, hastening the ripening and increasing the sugar. It has not been determined that it will uniformly produce this result. The character of the soil will probably modify the effect.

The higher parks of the State are not adapted to this culture, but good crops of rich beets have been grown in the San Luis valley at an altitude of rather more than seventy-five hundred feet.

The beet growing almost wholly under ground in this State, the loss in trimming is reduced to a minimum. Experiments indicate about 13 per cent. loss.

The amount of sugar in the crown of the beet, as it grows with us, is about one per cent. less than there is in the beet.

The cost of growing and harvesting an acre of beets will, of course, vary, but it is not far from thirty dollars per acre, exclusive of ground rent.

The growing of this crop will be more successful and the cost often materially lessened by the exercise of good judgment on the part of the cultivator. Specific rules for its culture, applicable to every case, cannot be laid down, and it must furthermore be remembered that even the very best rule can be so indifferently carried out that it may produce very poor results. No amount of experimentation can eliminate the difference between an intelligent, observing cultivator and one lacking these characteristics. Some land needs to be treated in a manner which would be wholly inapplicable in another case. Men who have tilled and irrigated their farm lands for years have learned how to treat each separate part of their farms. This knowledge is probably the secret of their success. No general statement regarding the culture of beets can be properly interpreted without taking these special facts into consideration.

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**Bulletin 64.** **June, 1901.**

# The Agricultural Experiment Station

OF THE

Agricultural College of Colorado.

# PRESS BULLETINS,

Nos. 1 to 11.

**PUBLISHED BY THE EXPERIMENT STATION**
**Fort Collins, Colorado.**
**1901.**

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## BULLETIN No. 1, SEPTEMBER, 1899.

# THE SUGAR-BEET CATERPILLAR.

BY CLARENCE P. GILLETTE.

The horde of caterpillars that have been devastating the beet fields during the past two weeks, between Palisade and Grand Junction, and that have occurred in small numbers from Grand Junction west towards Fruita, require the prompt attention of all interested in the success of the sugar beet culture in the Grand Valley, that the loss to this year's crop may be quickly checked and that severe losses for the coming year may be averted.

During the early part of the week (August 14th to 16th) the writer visited many beet fields in company with Mr. C. E. Mitchell and others, for the purpose of determining the nature and extent of the injuries, the length of time the attack is likely to continue, what remedies it will be best to apply, and other points of importance concerning the caterpillar.

The insect was found in the fields in all stages of development, except the egg. The caterpillars varied in size from those that did not exceed a sixteenth of an inch to the fully grown individuals that measured from an inch to an inch and a fourth in length. A large proportion were half grown or more, and many had changed already to the chrysalis or pupa state, just beneath the surface of the ground.

The fact that there are still many small worms makes it certain that the attack will continue to some extent to near the end of the present month (August). A quantity of the chrysalids were placed in suitable receptacles, and from them several moths, which are the adult insect, have appeared at this writing. The females are found to be heavily laden with immature eggs, and it is highly probable that within a few days these eggs will be deposited on or about the beets for a succeeding brood of worms. It is greatly to be hoped that the moths now hatching are only belated individuals of the second brood and that another full brood will not appear this summer. However this may be, not a day should be lost in beginning the work of destroying the caterpillars now upon the beets. If the present brood is allowed to mature, it means a greatly increased number of caterpillars to contend with next year. It is with insects as with plants. The greater the number allowed to mature this year, the greater will be the quantity of seeds sown, and the larger will be next year's crop. The old adage, "A stitch in time saves nine," is more than doubly true when dealing with the destruction of insect life.

The closest watch should be kept during the next two or three weeks for the appearance of small worms. If none seem to be present, look carefully among the small and tender leaves at the base of the large ones, where they may be found.

### REMEDIES.

A moderate number of friendly insects were found about the beets. These were lady-beetles, Aphis-lions and ground-beetles, all of which were probably preying to some extent upon the small caterpillars. Birds were very scarce in the beet fields; the crow seemed to be doing more than any others of the feathered tribe to destroy the caterpillars. It is plainly evident that the natural enemies are far too few to be of much service at present in keeping this insect within proper bounds. Artificial measures must be adopted to save a good partial crop of sugar beets over the eastern portion of the plantations about Grand Junction this year, and without these measures the crop over the whole valley may be largely a failure another year.

The caterpillars can be destroyed. The writer used both Paris green and kerosene emulsion, with satisfactory results, while at Grand Junction. The emulsion is more expensive and needs to be applied very thoroughly to give good results. The caterpillars should be thoroughly wet with it. This remedy would be specially useful on those fields where the caterpillars are very abundant and of large size and where the tops of the beets have been nearly or quite devoured. The chief benefit from destroying these caterpillars will be to lessen the number of the next brood.

By closely watching for the first appearance of the caterpillars when they are small, and then promptly and thoroughly treating the beets with Paris green or other arsenical poison, it is believed that the pest can be quite easily kept in check.

The poisons may be applied in a watery spray in the proportion of a pound of poison to 100 gallons of water.

Apply with force in a fine spray, and be thorough, but do not continue the spray in one place until the drops run together and carry the poison with them off the leaves. Where small patches are to be treated, a very simple method is to mix one pound of Paris green with about 20 pounds of common flour, and apply by dusting the mixture over the plants. This is readily done by placing a quantity of the poisoned flour in a small cheese cloth sack, which is held in the hand and shaken over the plants as the operator walks down the row of beets. This application can be best made when there is no wind and when there is a dew or rain upon the leaves to make the poison and flour stick.

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### No. 2, APRIL, 1900.

## COLORADO SUNSHINE.

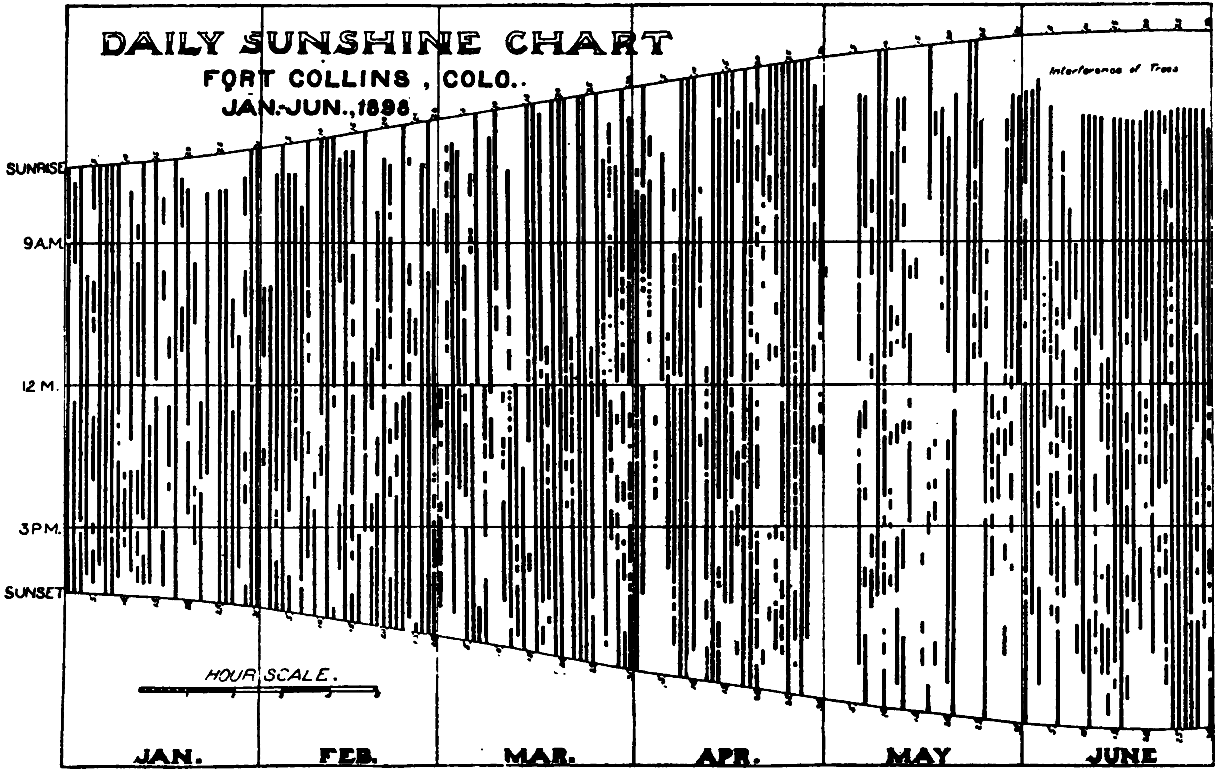
BY L. G. CARPENTER.

The important effect of sunshine on plants, their growth and development, their aromatic oils, the color of their flowers, and the quality and color of their fruit, is well known. That it has an equal influence on the spirits and health of man, is also well recognized. In general it has a beneficial influence on useful plants, while destructive to injurious ones, as molds, fungi, and bacteria. It is one of the most potent germicides. Most diseases cannot spread in the presence of sunshine.

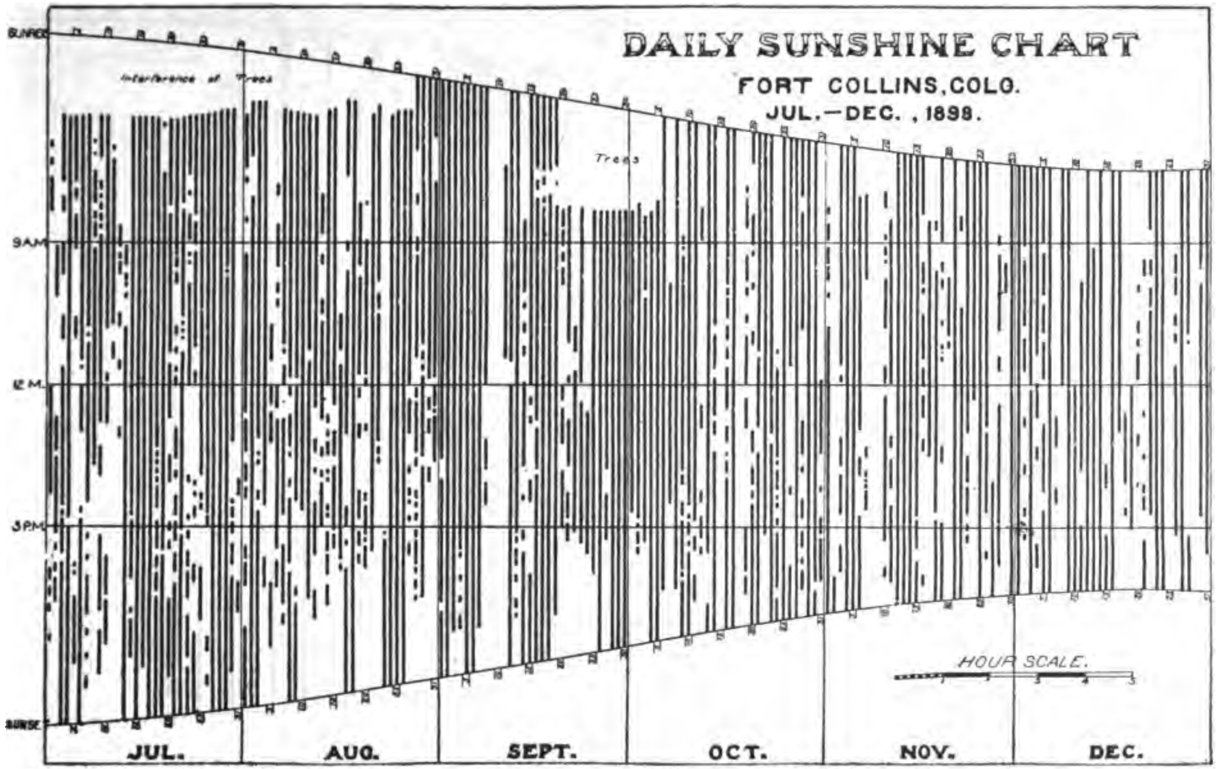
The following charts showing the sunshine day by day, throughout two years, are of more than passing interest, both from an agricultural and a sanitary standpoint. The record is made continuously at the Experiment Station.

The full lines show the sunshine. The breaks in the lines show when the sunshine was interrupted by clouds passing over the sun. The diagrams show at just what hours the sun shone on each day of these two years. Attention is called to the few days without some sunshine. May was the rainy month in 1898.

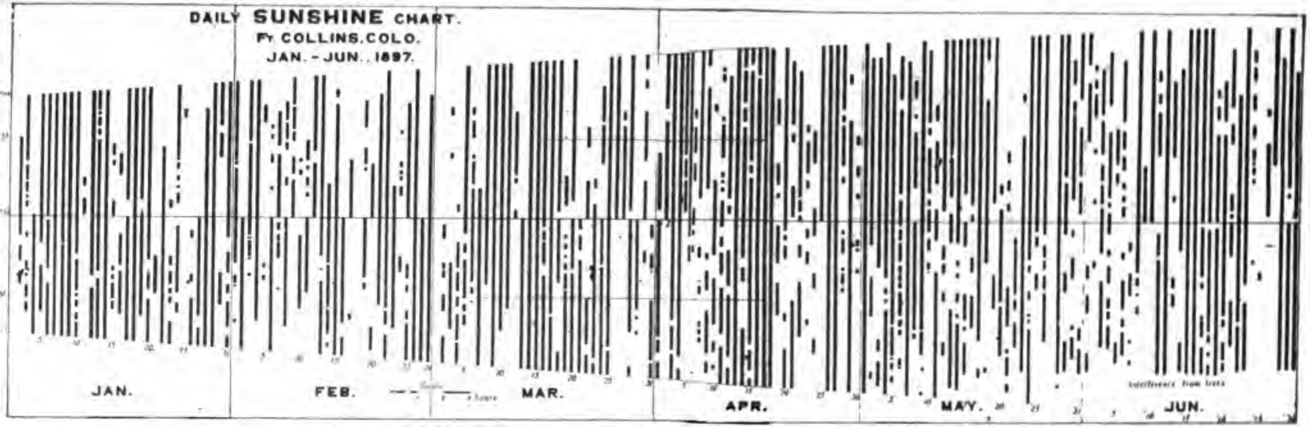
The record for 1897 is on one-half the scale of that of 1898.



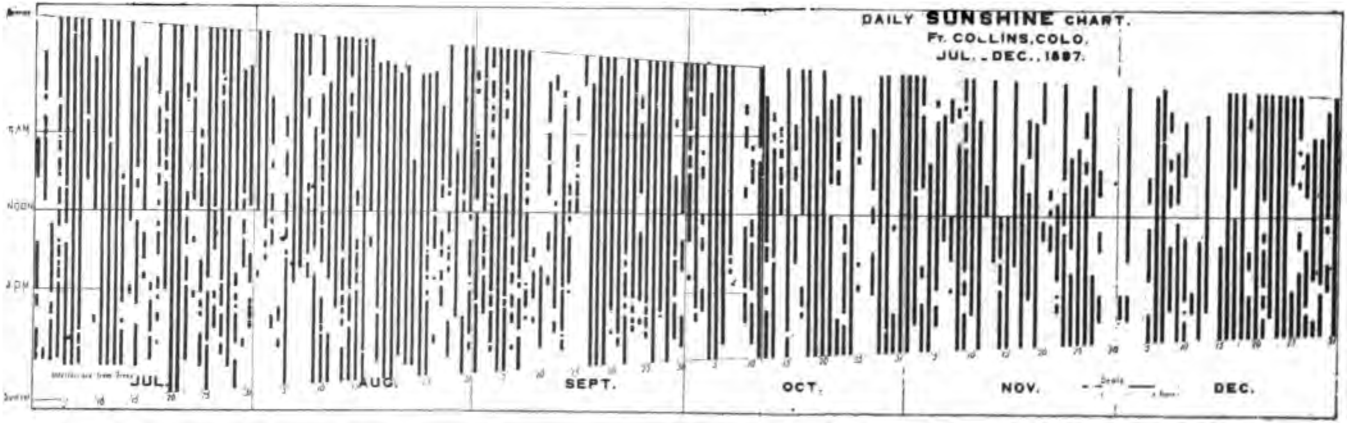
DAILY SUNSHINE CHART
FORT COLLINS, COLO.
JAN.-JUN., 1898



DAILY SUNSHINE CHART
FORT COLLINS, COLO.
JUL.—DEC., 1898.



DAILY **SUNSHINE** CHART.
FT. COLLINS, COLO.
JAN. - JUN., 1897.



DAILY **SUNSHINE** CHART.
FT. COLLINS, COLO.
JUL. - DEC., 1897.

## No. 3, MAY, 1900.

# THE BEET ARMY-WORM.

BY CLARENCE P. GILLETTE.

The caterpillar which did so much injury to sugar beets in the vicinity of Grand Junction last year will doubtless appear again this summer. While the insect has long been known to entomologists, last year was the first that it has ever been reported doing serious harm to any crop.

While the life habits of the insect have never been studied, it seems probable, from what the writer could learn of it last summer and fall, that it has two broods in the course of a year. The caterpillars that were so abundant during August last year entered the ground and then appeared again as moths in September. There were few enemies to destroy the caterpillars and the moths hatched in enormous numbers. These moths, like house-flies and mosquitos, seek every available place of protection from winter's storm and cold that they may live (hibernate) until spring. When vegetation starts the moths, laden with eggs, go in search of beets or other plants furnishing suitable food, to deposit their eggs and thus provide for an early brood of worms. If ten per cent. of the fall brood of moths survived the winter, there is serious danger that beets will fare worse this summer than they did last, unless growers are early on their guard to make thorough and timely application of effectual remedies. Just here let me warn all against experimenting with new or patent remedies which some friend or vendor may think entirely satisfactory. Use such remedies very cautiously and sparingly at first, or do not use threm at all.

From what could be gathered last summer, it seems that there was a first brood of caterpillars at about the time for thinning the beets, which, in some cases, destroyed most of the plants after thinning.

### REMEDIES.

Experiments tried last summer proved that the common poisons, Paris green, London purple, and white arsenic, will destroy the caterpillars if well distributed upon the beets. These poisons may be applied dry or in water. If the caterpillars appear upon the beets while the latter are small, I believe the best method of application is to mix one part by weight of Paris green or London purple with twenty parts of common flour, and then dust the mixture over the plants before sunrise in the morning. In this strength a light dusting will be sufficient. The early application is recommended, because the leaves have then a slight amount of moisture upon them, which helps to hold the flour and poison. Just after the leaves are moistened by a shower is also a good time to make the application.

To apply the poison, make a small cheesecloth sack about five inches in diameter and ten inches deep. Fill it with the mixture of poison and flour and walk along a row of plants shaking the sack over them. This can be done quite rapidly when one has learned how, is economical of poison, and does not require wheelbarrow or wagon to carry pump and tank.

When the plants become large, as in case of treatment for the second brood, it will probably be better to use a barrel or tank and spray pump.

If a spray is used, apply either Paris green or London purple in the proportion of a pound to 100 gallons of water and add two pounds of fresh lime for each pound of poison. The lime should be slaked and strained through a cloth to take out lumps. Then use a nozzle that throws a fine spray, and do not continue the application in any place long enough so that the drops sprayed upon the leaves will run together and flow off, carring the poison with them.

If white arsenic is used, prepare according to the following directions:

Put two pounds of white arsenic and eight pounds of sal soda together in a dish and boil for twenty minutes in two gallons of water, anu keep as a concentrated solution. *It is extremely posionous and should be placed at once where there is no possibility that children or domestic animals can get it. Also, label it "poison" in large letters.*

Then, in each 40 gallons of water, first slake four pounds of lime and then add slowly one quart of the concentrated solution while the whole is being stirred. The mixture is then ready for application, as in the case of Paris green. The lime should be strained through a cloth to take out the lumps.

I am advising the use of these poisons somewhat stronger than is common, but the experience of last year makes it seem advisable to do so.

Growers should keep the closest watch of their beets this year, in order not to let the caterpillars get the start of them. I hope to be notified of any appearance of these worms or other injurious insects promptly, and shall be glad to do all in my power to aid those who are anxious to save their crops from the attacks of such pests.

## No. 4, JUNE, 1900.

# THE CANTALOUPE BLIGHT.

BY H. H. GRIFFIN,

Rocky Ford, Colorado, has long been famous for its cantaloupes. Until of late the industry has moved along at a rapid pace, little disturbed by insects or plant diseases. The blight, or rust, was first noticed on a few patches in 1896. There was an increase of the disease in 1897, more especially on the same fields, but its spread was not suffient to cause much alarm. There was a vast extension of the disease in 1899 and the severity was much greater. The disease seemed to spread from a few well defined centres and grew less with distance from these centres. Many points in the Arkansas Valley report no injury. All evidence shows that the disease is not caused by any particular soil conditions, mode of irrigation, or peculiarity of climate.

The station began to investigate the question in 1898. Prof. Crandall, in 1899, pronounced the trouble due to a fungus, a new species named by Ellis and Everhart "*Macrosporium cucumerium.*"

Seed taken from diseased melons was planted in 1899 to see if the disease was communicated by the seed. Three rows, each 250 feet long, were planted May 12th. The middle row was sprayed with Bordeaux mixture to test its efficacy as a preventative, or, should the disease appear, for its control. Sprayings were given to the middle row June 22nd, June 30th, July 22nd, July 31st and August 11th. At the time of the first spraying there was no appearance of the blight, but at the time of the second spraying it was noted that "something on the leaves that looked like blight" had appeared. Previous to the 19th of June the weather had been very dry, so that if any infection had been present it is not probable that its spread would have been rapid enough to become apparent. After this moisture was plentiful; seven inches of rain fell in July; 5.14 inches in the week commencing July 14th. These rains submerged the vines and could not fail to wash off the spray. At the third spraying the blight was strongly in evidence. In August 2.22 inches of rain fell and dews were prevalent. A decided benefit was derived from the sprayings made after the 22nd of July. The sprayed vines held up comparatively well, and the fruit was of good quality. On the unsprayed vines the fruit ripened prematurely; they were insipid in taste, and it could be detected from which vines they were picked. The sprayed vines remained green and in a growing condition for two or three weeks after the others had succumbed. The plants grown from diseased seed did not seem to be more susceptible than those grown from seed from healthy vines.

Other experiments were inaugurated in the latter part of July on a more extensive scale. Both the Bordeaux mixture and an ammoniacal copper carbonate solution were used on different vines at each place. The first spraying with the Bordeaux mixture was given July 27th and the last August 18th. The carbonate was first used August 4th and and the last spraying was made August 18th.

The test was made on seven rows, each 275 feet long, the vines that were sprayed remaining in good condition fully ten days after the others were gone. The melons ripened slower, in better condition, and were of uniformly good quality.

The results from the carbonate were not so pronounced as from the Bordeaux mixture. The results from the above work were so promising that it was tested on a still more extensive scale. About ⅛ of an acre of melons belonging to Senator Swink were sprayed. About one acre was sprayed for Mr. John Deweese, and one and three-fourth acres for Mr. C. S. Fenlason. Only one application was made at these places. These sprayings were done late in the season, when the blight was spreading rapidly. These melons were surrounded by others that were blighting badly.

The work confirmed the result of the other trials. Mr. Fenlason sold 300 crates of good melons from his sprayed field.

The virtue of the spraying lies largely in the ability of the melons to ripen properly, *i. e.*, to perfect the quality; the benefit is not alone to the vine.

It took 22 pounds of bluestone to spray the vines at Mr. Fenlason's, which were very large. The estimated cost was $6.75 per acre. Had the work been done earlier the cost would have been much less.

## APPEARANCE OF THE DISEASE.

The cantaloupe blight is caused by a true parasitic fungus. To the casual observer the first appearance is a large number of small brown spots upon the leaves in the center of the hill. If the younger leaves are examined, it will be seen when the fungus is at work some time before the brown spots make their appearance. It can be seen when the leaf tissue has been eaten away, and when the injured tissue dies the brown appearance occurs. These brown spots grow larger as the fungus kills the tissue, until they become so numerous as to envelop the whole leaf; it appears as though struck by frost. It is surprising how quickly the spray will prevent the enlargement of these spots upon the leaf. At the time spraying is required the melon vine is making quite rapid growth, which necessitates spraying at intervals in order to cover the new growths.

### HOW THE ACTION IS PERFORMED.

It can be readily seen that if some material is put upon the leaves that will kill the fungus, without injuring the host plant, the desired action is performed.

No fear need be felt that the bees will be poisoned. A number of hives stood near one of the fields treated, but no dead bees were found nor could it be seen that any injury resulted to them.

From the work of this season, we can advise that two or three spraying be given should the weather conditions prove favorable for the spread of the disease. If a dry season occurs perhaps the disease will not develop to any injurious extent.

From our present knowledge we should say that the first spraying should be done about the middle of July, followed every ten days until two or more are given, depending upon the weather. It would be well to follow the first rains of July with a spray.

Directions for making Bordeaux Mixture for use upon cantaloupes:

Dissolve 6 lbs of bluestone.
Slack 4 lbs. of fresh lime.

When the lime has become cool strain off the milk, adding it to the bluestone. Add water until there are 40 gallons.

No. 5, JULY, 1900.

# THE RUSSIAN THISTLE AS FORAGE.

BY J. E. PAYNE,

In many localities, the Russian thistle threatens to take possession of the land, in spite of all efforts of public-spirited people to keep it in check.

In neighborhoods where it has taken possession of the land, it seems best to ask—Can it be used for the benefit of the people whose land it has invaded?

The value of the Russian thistle has never been tested by a feeding experiment at any Experiment Station so far as we know, but the Minnesota Station has analysed the plants in various stages of growth. The following, copied from the Experiment Station Record, page 553, Vol. 6, gives the substance of Bulletin No. 34 of the Minnesota Experiment Station:

> "When young the thistle is claimed to have a high food value, especially for sheep, which, some claim, are attracted to it merely on account of the salt which it contains. The chemical analysis shows a large percentage of ash material, amounting to nearly one-fifth of the dry weight of the plant. This is a serious objection to its use as a fodder plant, on account of the alkaline nature of the mineral matter present. One favorable point, as shown by analysis, is the large amount of nitrogenous matter present, being as much as there is in clover or rape. Before the development of the thorns, there is not much fibre present; at this time the plant is more valuable as a food than when mature. When the plant is ripe, the fibre and mineral matter make up half its composition, and although rich in nitrogenous matter, the former elements greatly reduce its feeding value
>
> "The ash analysis shows that the weed has strong foraging powers, there being large amounts of potash and lime taken up by the plant. The draft which the plant makes upon the sodium in the soil is a benefit to alkali lands. The amount of sodium present varies greatly with conditions, showing that the plant is able to adapt itself to the alkaline conditions of the soil. From the time the thorns are out until the plant matures it takes up a large amount of sodium from the soil, and only small amounts of other materials, hence it makes the heaviest draft upon its soil while in an immature state, after which it takes but little essential plant food."

The following testimony concerning the use of Russian thistles as a food for stock has been gathered from men who have had more or less experience in feeding it:

"Cattle eat Russian thistles, but they are poor feed."

CHAS. HACKENBERGER,
Burlington, Colo.

"Cattle will eat Russian thistles in large quantities. They physic cattle."

THOMAS SEAMAN,
Wallet, Colo.

"Cattle eat Russian thistles. They seem to do well on them."

ELMER BROWN,
Wallet, Colo.

"I am feeding my bulls, which I keep up, Russian thistle hay. Consider it good feed when cut before the thorns harden."

SAMUEL P. SHAW,
Lamborn, Kansas.

"During the winter of 1899-1900, I fed a part of my cattle millet, and the remainder, about 40 head, Russian thistle hay. Those fed Russian thistles wintered fully as well as those fed millet. Fed none except during storms. Fed Russian thistles to those that were the best rustlers"

LEO THOMAN,
Burlington, Colo.

"In June, 1895, my cows fed on young Russian thistles. I never made better butter nor more of it than I did that month."

A. C. WILLS,
Lamborn, Kansas.

"My sheep eat Russian thistles, both green and dry. I think a patch of Russian thistles worth as much, for sheep feed, as the same area in grass."

WM. LANG,
Cheyenne Wells, Colo.

"When I first began farming here, when wheat failed I had no feed for stock. Now, when wheat fails, Russian thistles take posession of the ground. I cut these and winter my cattle on them."

JOSEPH RUBY,
Thurman, Colo.

The investigation has not been carried far enough to warrant us in recommending the Russian thistle as a hay plant when there is plenty of other forage. But the above testimony convinces us that those whose land is occupied by the thistles should cut some and try them as a feed for stock.

## No. 6, DECEMBER, 1900.

# A SO-CALLED BLIGHT CURE.

BY CARL H. POTTER,

The "Woodbury Blight Cure" as its name implies, is a proprietary article that has recently been placed on the market. This "cure" is guaranteed to be a certain remedy for the blight of apple and pear trees if used as directed, and a destroyer of insect pests as well. Two mixtures are sold by the company controlling the cure, a body wash and a summer spray. The claims for the remedies and the directions for their use, as set forth by the company, are as follows: *

> "The body wash should be used at least once during the season, preferably early in the spring on account of sun scald, but of immense benefit any time in the year.
>
> "The summer spray should be used at least three times during the season for the cure of the blight and the destruction of insect pests. It should be used after, or during, every severe electrical storm for an insurance against the twig blight.
>
> "Spray the first time when the trees begin to leaf, again from the middle to the last of July. Follow these directions carefully, and we will guarantee a cure for blight and the practical destruction of the codling moth and other injurious insects. The spray is beneficial and will promote a strong, healthy growth in all plant life, more especially on roses and vines. It will destroy slugs and green flies in the green-house."

On account of the fact that a large sale of such cure had been made, and that many inquiries had come to the Station, it seemed proper for a trial to be made.

June 29, 1898, a number of bearing apple trees in the Station orchards were selected and prepared for trial. Four distinct series or lots of trees were treated, while the others, as similar as it was possible to select them, were wholly untreated. These entered the test merely as checks with which to compare the trees that were treated. All of the trees to which the remedies were applied were recorded as class "A," while the untreated, or check trees, were class "C."

The different series of trees comprised summer, fall, and winter apples, and varied from very slight affection of the twigs to quite severe cases of blight, in which many of the smaller limbs were entirely diseased, the blight even forming large and more or less concentric patches on the

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* From printed directions provided by the company.

larger limbs about the bases of the smaller ones. The trunks were not very badly affected by blight, yet there was plenty present for a test. Those trunks that were rough, whether in class "A" or class "C," were thoroughly scraped before treatment.

On the afternoon of June 29th the trunks and the lower portions of the limbs, to a height of about four feet from the ground, of the trees of class "A" were treated to an application of Woodbury's "wash," the material being applied with a stiff paint brush. About one quart of the mixture was used for each tree.

The following afternoon, June 30th, the same trees were thoroughly sprayed with the "spray mixture." The mixture was used double strength, as the directions recommended where an early spraying had not been given. The material was thoroughly stirred and then diluted to the strength of ⅘ of a quart of "wash" to 4⅘ gallons of water. Five gallons of this diluted mixture were used on each tree, the services of one man being constantly required to agitate the liquid in the box of the spraying pump. Blighted parts received especial attention.

August 13th all of the trees in class "A" were sprayed as before, except that the spray or "cure" was used as diluted in the proportion of one part of spray to 49 parts of water. November 15th the trunks of all the trees in class "A" were washed as before.

April 18, 1899, the trunks were again painted with the wash, a very thorough job being done. The trees were entirely dormant.

April 21st. Trees sprayed as per directions. Still dormant.

July 19th. Trees again sprayed as per directions.

This completed the application of the remedies to the trees. They had been used nearly two seasons, and were carefully and conscentiously applied. Frequent and careful observations of the trees were made, not only during the two seasons named, but extending through the season just closed. *We have not been able to detect, in any way, the slightest benefit to the trees as result of the use of these materials.*

Concerning the value of the spray as an insecticide, Prof. Gillette makes the following statement:

> "I have tested the 'Woodbury Blight Cure,' summer spray, upon both leaf-eating and sap-sucking insects, and in no case did it seem to have any injurious effect upon the insects treated. Leaves thoroughly wet with the solution were eaten by insects which afterward matured in perfect condition."

## No. 7, FEBRUARY, 1901.

# THE SEEPAGE MEASUREMENTS OF THE EXPERIMENT STATION.

BY L. G. CARPENTER.

One of the effects due to irrigation that is noticed in all countries is the seepage water which returns from irrigation and enters the streams. This is so much that streams may be drained dry and, within a short distance, again have an appreciable quantity of water..

At the suggestion of Hon. B. S. LaGrange, President of The State Board of Agriculture, and at that time Water Commissioner of District No. 3, a measurement was made in 1885 of the Poudre River by the State Engineer's office, and two others were made in 1889 and 1890. In 1891 the Experiment Station took up the matter to investigate in detail the amount and the laws of the increase. Such measurements have since been carried on annually on the whole length of streams in the State, from their exit from the mountains to the State line. These include the Cache a la Poudre, the South Platte, the Big and Little Thompson, the St. Vrain and Left Hand creeks, Boulder and South Boulder, Clear Creek, Bear Creek, the Arkansas from the mountains above Canon City to the Kansas State line, the Rio Grande from near Creede to the New Mexico line, and the Conejos. Of these, measurements have have been made for four years on the Arkansas and for five years on the Rio Grande, and the others for varying times.

It has been the intention to extend these measurements to other parts of the State as soon as time and means permitted. During the past year, 1900, the measurements were begun on the Western Slope, and were made on the Uncompahgre River from Ouray to Delta. These measurements have required every foot of the streams to be passed over, every headgate visited, every stream that leaves the river, as well as those which flow into it, to be measured. This has required the traveling over, in detail, of very nearly one thousand miles of river during the past season, and from six to eight hundred miles for each of the past four years. In all, some five thousand miles, at least, of river measurements have been made.

A report, giving the results of investigations up to that date, was issued in Bulletin 33. This discussed the relation of the seepage to the area irrigated and to the amount of water applied, as well as the rapidity of the flow of the waters under ground, and showed that the value of this source of water supply amounted to several hundreds of thousands of dollars.

This bulletin has been very widely quoted. The more recent measurements have been given in the annual reports of the Experiment Station, and in the report of the State Engineer. Bulletins discussing these measurements, and comparing them, will soon be issued by the Experiment Station.

In addition to these measurements the Experiment Station has also made hundreds of miles of measurements on canals to determine the amount of loss by seepage from canals, the means of preventing the seepage, and the means of protecting lands from such damage. It is studying the character of the water used in irrigation, the amount of water used in irrigation, and other phases of the irrigation question.

### No. 8, APRIL, 1901.

# POTATO FAILURES.

BY W. PADDOCK AND F. M. ROLFS.

The Experiment Station has received a number of inquiries from potato growers in various sections of the State in regard to the failure of the potato crop in certain seasons. These failures seem difficult to explain, since there is little blight in evidence, and they occur with experienced growers as well as with beginners, and on soil that would seem to be in a good state of fertility. In some instances the vines are said to have made a luxuriant growth and remained green until late in the season, but when digging time came the tubers were found to be much under size. In other instances a large growth of vines were found to have set an abnormal number of tubers which failed to develop.

At first thought it would seem that some of the elements necessary to the growth of the potato plants were lacking in the soil, and this may be true in some instances, but it will not explain all the failures. Certain fungi or plant diseases have been found to be abundant on the potatoes in various parts of the State, which may have something to do in producing these conditions. One of these diseases has been known in America as a potato disease * less than a year, though it has undoubtedly been present in our potato field for a long time. In Europe it is considered to be one of the most destructive potato diseases. The fungus does not confine its attacks to potatoes alone, but is found in a great variety of plants, including alfalfa, clover and sugar beets.

The disease attacks the potato plant just below ground, cutting off free communication between foliage and tubers. In extreme cases the plants may be killed, and much of the so-called late blight or early ripening of the vines may be due to this disease.

The fungus lives over winter on the stems and tubers of the potato, and on various other plants. The fungus adheres to the tubers in the form of dark patches which resemble bits of soil, and which vary in size from that of a mere speck

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* Dugger and Stewart, Bulletin 186, p. 17, N. Y. State Experiment Station, and Bulletin 186, p. 63, N. Y. Cornell Experiment Station.

to areas a half inch or more in diameter. The fungus does not injure the potatoes directly, but it detracts from the appearance of the tubers when offered for sale. But the important point is, that when infected potatoes are planted the fungus is planted with them, and thus the disease is propagated year after year.

The fact that the fungus attacks the roots of alfalfa complicates the treatment, since alfalfa is commonly used in the rotation of crops. If potatoes free from the disease are planted on land which has been in alfalfa within two years, the chances are that the crop will be affected, providing there has been any of the fungus on the alfalfa plants. The length of time that the fungus will live in the soil is not known. German authorities state that it will persist for at least three years. Neither has the kind of crop which should be grown on infected land to starve the fungus been definitely determined; however, it is not known to attack our common cereal crops.

It is too early to recommend a line of treatment to overcome the above conditions, since the cause of the trouble is not positively known, but potato growers who have been troubled in this way may find it profitable to take certain sanitary precautions. Such measures consist in planting potatoes, on land on which potatoes, beets, alfalfa or clover have not been grown for at least three years, and potatoes that are free from disease should be used for planting. If there is reason to suspect that the seed potatoes are infected with fungi, they may be treated with corrosive sublimate or formaline, as is recommended for potato scab.

## Formulæ for Treating Diseased Seed Potatoes. *

| | |
|---|---|
| Corrosive sublimate | 1 ounce |
| Water | 8 gallons |

Dissolve the corrosive sublimate in one gallon of hot water, then dilute with seven gallons of water. Allow the potatoes to soak one and one-half hours. When dry they may be cut and planted, though it has been found to be a good practice to treat the potatoes a week or more before planting, since the treatment may retard germination if done just before planting.

Corrosive sublimate is a deadly poison, and it should be used in wooden or earthen vessels, since it corrodes metals.

| | |
|---|---|
| Formaline | 8 ounces |
| Water | 15 gallons |

Soak the potatoes two hours in this solution, preferably but a short time before planting. This solution is somewhat more expensive than the corrosive sublimate treatment but has the advantage of being non-poisonous, and it may be used in any kind of a vessel.

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* Jones, L. R., and Edson, A. W., Vt. Sta. Bul., 85.

## No. 9. APRIL, 1901.

# SUNSHINE FOR 1900.

BY L. G. CARPENTER.

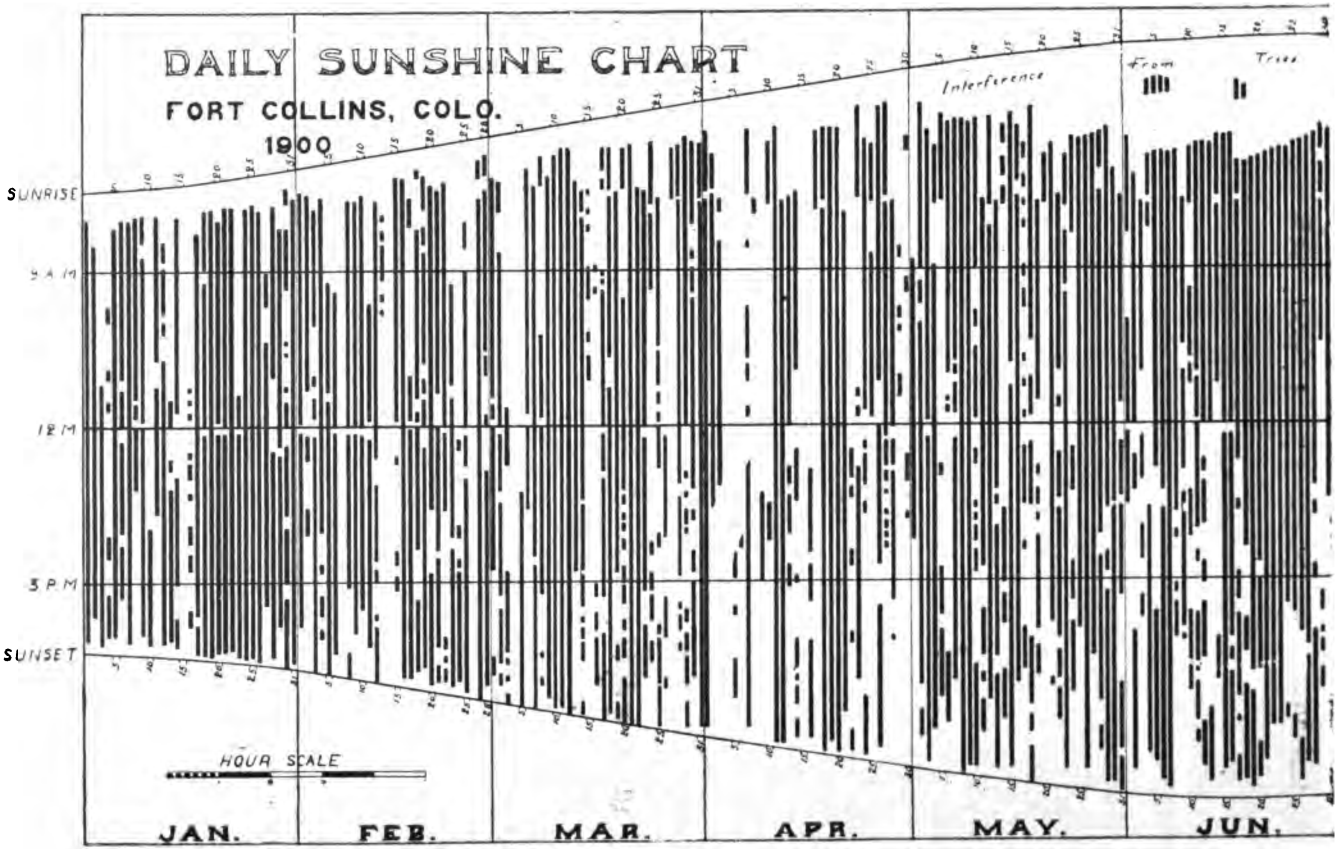
While the pleasure afforded by a sunny day is of common experience, the value of sunshine as an element in the climate, whether from the standpoint of health or spirits or of agriculture, is not often given the importance it deserves. Until recently no attempt has been made to record the amount or intensity, even in those places specially interested in agricultural meteorology.

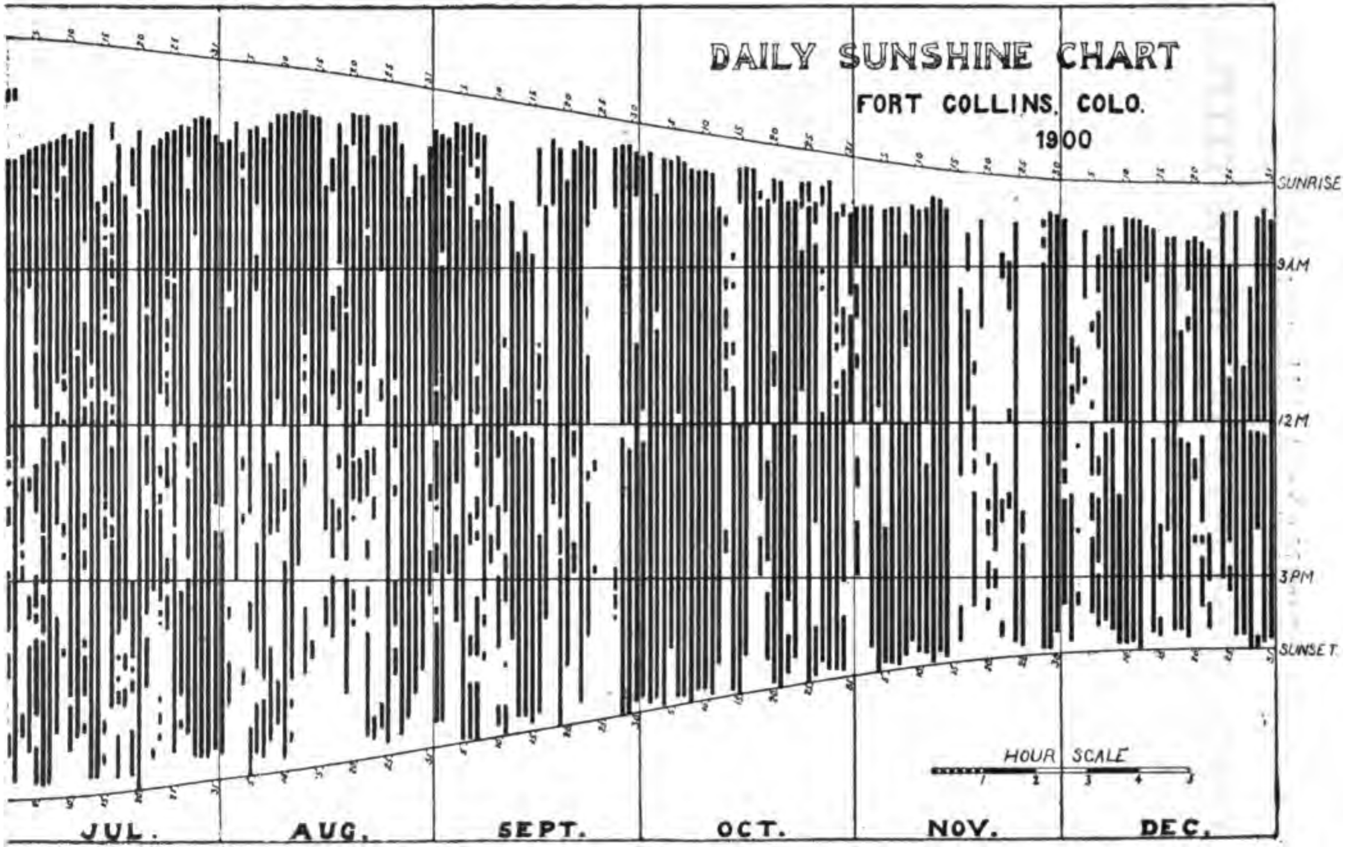
A certain amount of sunlight is recognized as a necessity for plant growth, for without it the development will be absent or unhealthy. With an increase in sunlight there is almost always an improvement in quality, and in the amount of essential oils; or in special qualities, as in sweetness, and an increase in the color of fruits and flowers. There is a decrease in the prevalence of certain diseases with direct sunshine. It has been known from time immemorial that dirt and darkness were conditions favorable for disease, while cleanliness and light were unfavorable. Molds and fungi, and the invisible but perhaps more important bacteria, do not thrive in sunshine. Even in diffused light few bacteria develop, and direct sunshine is destructive to most, if not to all, injurious forms within a short time. Sunshine and the drying action of the air are unfavorable to such forms of life, and are Nature's chief disinfectants.

A sunny climate or a sunny home is thus more apt to give the conditions for such physical health as are necessary to permit of sunny dispositions.

The charts show the amount of sunshine at Fort Collins for 1900, as recorded by an automatic photographic recorder and then transferred to the diagram.

A line is given to each day. The black line shows the duration of the sunshine and the hours at which it shone. When broken or absent, clouds are indicated. The longer the break, the longer the duration of the cloudiness. The diagram therefore shows the exact hours at which the sun shone during the year. It is noticeable that the forenoon had more sunshine than the afternoon, and that the winter months had comparatively little cloudiness. The relative amounts vary in different seasons, as a comparison with the charts in Press Bulletin No. 2 of 1900 will show.


DAILY SUNSHINE CHART
FORT COLLINS, COLO.
1900



DAILY SUNSHINE CHART

FORT COLLINS, COLO.

1900

### No. 10, APRIL, 1901.

# CONCLUSIONS RELATIVE TO THE CULTURE OF SUGAR BEETS.*

BY W. P. HEADDEN.

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* This appears as a Summary of Bulletin 63. A Resume of the Publications of the Colorado Agricultural Experiment Station, and is not here reprinted.

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### No. 11, APRIL, 1901.

# HOW TO FIGHT THE CODLING MOTH.

BY CLARENCE P. GILLETTE.

Many orchardists spray for the codling moth and still grow very wormy apples. The writer knows of an orchard near the Experiment Station that was sprayed with an arsenical mixture three times last summer and in which fully 80 per cent. of the fruit was wormy at the time of picking in September. Another orchard in the same neighborhood was sprayed twice and had less than 2 per cent. of wormy fruit at picking time. What made the difference? Why is it that one man sprays his orchard and has very little wormy fruit and his neighbor, who also sprays, has nearly all of his apples wormy? This is a question often asked and frequently difficult to answer satisfactorily. That a reason exists for the different results there can be no doubt. The object of this paper is to give the best directions that we can at present for the successful treatment of this insect. Perhaps it will explain to some why they have not met with better success in the past.

## WHEN TO SPRAY.

No date can be fixed upon, yet spraying *must be done at the right time* if the best results are to be obtained. The *right time* is immediately after the blossoms fall and before the calces of the forming apples close. If there are belated blossoms on the trees after the great mass of bloom has fallen, do not wait for them if some of the calces are closing. If the trees do not all bloom nearly together, spray the early blooming trees first and then in a few days spray the others. Repeat the application in one week, or, at the latest, ten days.

### HOW TO SPRAY.

Be thorough with the work. It will take more time and material, but if spraying for this insect will pay at all it will pay best to do the work well. Use a nozzle that throws a medium fine spray, not a mist, and direct it so that the liquid will be thrown *into* every blossom or calx. A misty spray will not carry as well into the blossoms. To make a thorough application, it will be necessary to direct the spray from, at least, two sides of the tree, and if the tree is large, it will be almost necessary to apply from all four sides. In many orchards the trees are so closely set, so large, and poorly pruned, that it is impossible to make a thoroughly good treatment for the destruction of codling moth larvæ.

The one who directs the nozzle for the spraying will find it a great advantage to be elevated as high as the bed of a wagon box at least. If the trees are large, it will be well to use a step-ladder or a dry goods box in the wagon to elevate him still more.

### NUMBER OF APPLICATIONS.

Orchardists differ widely in opinion as to the number of applications that should be made. Some, noticing that the worms are most abundant late in the summer, think that spraying should be continued throughout the season of growth and report excellent results from spraying five or six or more times. However, it is the opinion of those who have tested the matter most thoroughly at the various experiment stations of the country that it does not pay to spray more than twice, if the two applications are properly made at the best time.

### POISON TO USE.

Here again opinions differ. Probably Paris green is as effectual as any if well applied and if the liquid is kept thoroughly agitated during the spraying. Scheele's green would probably be as effectual as Paris green, is cheaper, and remains in suspension in water better. London purple and arsenate of lime are readily kept in suspension in water but are slower in their action than the above mentioned poisons, and probably less effectual in their death-dealing power. They have the advantage of being very cheap. Arsenate of lead is kept in suspension without difficulty and is remarkable for its adhesive quality and its entire harmlessness to foliage unless used in great excess. It kills slowly and its value for the destruction of the codling moth has not been very definitely determined.

## PREPARATION OF THE POISONS.

*Paris green, Scheele's green and London purple* may be used in the proportion of 1 pound to 160 gallons of water. It is best to mix the poison in a small amount of water first and then in the full amount for which it was prepared. For each pound of poison used, add to the water one or two pounds of freshly slaked lime. This will lessen the liability of the poison to burn foliage.

*Arsenate of lime*, by the Kedzie formula is prepared as follows: "Boil two pounds of white arsenic and eight pounds of salsoda for fifteen minutes in two gallons of water. Put into a jug and label 'poison'. When ready to spray, slake two pounds of lime and stir into 40 gallons of water, adding a pint of mixture from the jug."

If this formula is followed, be sure to use a full measure of fresh lump lime, otherwise some of the arsenic will be left in solution in the water and will kill the foliage.

A somewhat simpler method of preparing arsenate of lime is to boil together for three-quarters of an hour 1 pound of white arsenic, 2 pounds fresh lime, 1 gallon water. Use one quart of this to an ordinary barrel of water (about 40 gallons).

If a stock solution of this poison is kept, be sure to label it plainly "poison," and it would be well to put in some kind of coloring matter besides.

If arsenate of lead is employed, use not less than one and one-half pounds to 50 gallons of water. Lime need not be added to this preparation.

If more than two applications are made, do not use the poisons in more than two-thirds of the above strengths after the second treatment.

## OTHER REMEDIAL AND PREVENTIVE MEASURES.

*Bandages* of burlap or other cheap fabric placed about the trunks of the trees from the middle of June till September will collect large numbers of the larvæ which gather beneath them for the purpose of changing to the pupa and then to the moth stage. If these bands are removed once in a week or ten days, quite a large percentage of the worms may be collected and destroyed. A bandage four inches wide and having two or three thicknesses of cloth is of good size and may be held in place by means of a single carpet tack thrust through the overlapping ends into the bark of the tree. A band thus held may be quickly taken off and replaced.

*Gathering and destroying fallen fruit*, either by hand or by means of hogs or sheep turned into the orchard, will help some to keep the codling moth in check, but most of the worms leave the apples before they fall. After apples have lain on the ground for three or four days almost no worms can be found in them.

*Protect cellar doors and windows* with screens wherever apples are kept so that moths hatching in the cellar cannot escape to the orchard.

*Clean culture* and the removal of all rubbish in and about the orchard will make it more difficult for the worms to find a suitable hiding place for the winter.

*Scraping the loose bark* from trunk and branches will also remove many safe hiding places for worms during winter.

No one should be discouraged because he does not meet with as complete success in the use of the above remedies as he had hoped the first year. He who persistently and intelligently uses them through a series of years will be almost certain of a degree of success that will convince him of their value.

**Bulletin 65.** **September, 1901**

The Agricultural Experiment Station

OF THE

Agricultural College of Colorado.

# A SOIL STUDY.

## PART III.

# THE SOIL.

—BY—

**WILLIAM P. HEADDEN.**

**PUBLISHED BY THE EXPERIMENT STATION**
**Fort Collins, Colorado.**
**1901.**

# The Agricultural Experiment Station,

FORT COLLINS, COLORADO.

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# A SOIL STUDY:

## Part III. THE SOIL.

By WILLIAM P. HEADDEN, A. M., PH. D.

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[*For convenience of reference the principal paragraphs are numbered, and a table of contents placed at the end of the bulletin.*]

§ 1. Bulletins 46 and 58 contain the results of our observations upon the effects of the mechanical condition, the "alkalis" contained in, and the general properties of this soil upon the crops grown on it. This bulletin forms the continuation of our study, and will treat of the soil itself. The preceding bulletins have treated of the crops; this will have nothing to do with them.

The crops grown were, with one exception, sugar beets. This soil, judged by the crops it has yielded, is abundantly rich in plant food. The crops obtained are more conclusive in regard to this point than the indications of the chemical analyses. In this case, however, the two methods of judging lead to the same conclusion, *i. e.*, that any failure of plants to grow is not due to a lack of fertility.

### REASONS FOR CHOOSING THIS PLOT OF GROUND.

§ 2. The choice of this particular piece of ground for study was determined by the fact that it was considered to be the most strongly alkalized plot to be found on the College Farm. It had been cultivated previously, but no crop was obtained. It was next set to forest trees, but the most of them died, only a very few surviving the first season, and the surviving plants were unhealthy. The roots of the young trees which were set out in the spring of 1896 were blackened by the soil, and did not seem to have grown at all. There is no reason to doubt but that this was due to the soil conditions, for the mortality among the plants varied with the soil in which they were set. In portions of this forestry plot, which included the plot made the subject of this study, the young trees lived well, whether they made trees or not. The soil and its condition, however, was quite different. This fact eliminates several questions, such as the condition and vitality of the young trees at the time of setting, the manner of setting and their subsequent treatment. The failure of the forestry experiment in this portion of the plantation was quite certainly due to the soil. To be more specific, it was due either to the salts present in the soil, to the soil being so wet as to prevent a sufficiently free access of the atmosphere, or to some other unfavorable condition. The presumption was that such large quantities of salts as were evidently present were quite sufficient to prevent, by their direct action, the development of the plants without considering their effect upon the soil.

### OUR ORIGINAL OBJECT EXTENDED.

§ 3. The primary object of the study was to determine, if possible, the effects of these salts upon certain crops, to see if their accumulation could be prevented or hindered by cropping, or even removed by cropping to sugar beets after they had accumulated to the extent of producing a decided alkalization of the soil. As we stated in Bulletin 46, the beet crop did not remove more soda salts from the soil under these conditions than under ordinary conditions, and it became necessary to extend our study in order to obtain an answer to our inquiry as to how we could ameliorate such conditions. The question assumed such shape that we found ourselves almost compelled to address ourselves to the study of the soil itself.

### THE APPLICATION OF GYPSUM NOT ADVANTAGEOUS.

§ 4. There is a general impression entertained by some that the application of gypsum to our alkalized soils would mitigate the bad effects of these salts. This opinion has found some support from the results of its use in California. The cases are entirely different. We have not the conditions that the Californians have, and the benefits obtained by the application of gypsum in their case, will not appear in ours. The character of our " alkali " is such that we cannot expect any benefit from the use of gypsum. In our particular case its addition would be a waste of material and a loss of labor, the soil being already so full of this salt that it can easily be recognized as crystalline aggregates disseminated through the soil, often giving it a mottled appearance. The addition of more gypsum under such conditions would be utterly useless.

### THE CHARACTER OF THE SOIL.

§ 5. The soil itself, as was stated in Bulletin 46, varies in its character from a loamy soil with a calcareous, clayey subsoil, to a fine alluvium resting upon a stratum of gravel, separated from it by a rather compact clay, but with no proper hard pan. The whole soil is very retentive of moisture, and it is difficult to determine whether there is any direct draining of the water from the alluvial soil above into the gravel stratum below or not. The configuration of the surface would justify the assumption that there is no hydrostatic pressure upon the water in the gravel stratum; at most it can scarcely be enough to force the water through the clay into the soil above. This would lead us to the surmise that the water in the gravel may be entirely different from the water in the overlying soil. Analyses made in the early part of our work corroborated this view.

### DRAINAGE.

§ 6. The drainage of the area, of which the plot under observation forms a part, is into the Cache a la Poudre river, at a point about one and three quarters miles below the town of Fort Collins. There is at present an open ditch running through this swale for a considerable distance, and the College management has laid tile drains for a long distance, serving to extend the drainage system almost to the line of the College property. The lateral drains are laid with four inch tiles; the main drains with six, eight and ten inch tiles. On the lower portion of the property there are two drains, laid with eight and ten inch tiles. These drains are parallel for a portion of their length and in part divergent.

§ 7. A study of the country shows that this swale was formerly the bed of a considerable stream formed by the union of streams issuing from the foothills through Spring, Dixon, Soldier and probably what is now the Poudre canon. This fact accounts for the strata of gravel and sand encountered in and along the margins of the swale.

The foundation of the Chemical Laboratory, situated on the north side of the swale, had to be put down to a depth of 20 feet on account of quicksands. At this depth, however, the workmen encountered a stratum of course gravel.

The fall from the plot of ground under observation to the Poudre river is about 150 feet, more rather than less. This old water course is now filled up. Ten or twelve years ago this plot of ground was very wet and boggy, the principal vegetation being cat-tails. This condition was undoubtedly due to the character of the soil, which, as I have stated, is very retentive of water.

### ORIGIN OF THE SOIL.

§ 8. The source of this soil is evident and will not account for the alkali salts or its physical properties. The gravel, where there is any at all, is clearly granitic, and can not be the residue from the breaking down of the younger formations of the foothills and plains. The mechanical analysis of the soil shows that even the finest sand is granitic and has been derived from the mountains within the foothills, carried and deposited by the waters which at one time had this swale for their bed. The only evidence that any of the soil material is of different origin is the occurrence, now and then, of a fragment of an impure limestone, which lies just out side the first hogback and belongs to the Fort Benton group or of sandstone belonging to the Juratrias. These fragments are quite rare and are the only definite proof that I have discovered that any portion of the soil has been derived from any other source than the granitic area of the mountains proper. The abundance of mica and red orthoclase in the coarser portions of the soil, and even in the silt, leaves no doubt but that this is the source of the material.

Some of the material may be the residue of strata belonging to formations of later or post cretaceous times, whose removal by waters, now represented by the Poudre river, has left some of this material. This is undoubtedly true of much of the plains soil, but probably only to a very limited extent of the soils of these old water courses.

### SOURCE OF THE ALKALIES.

§ 9. The alkalies are not so easily traced. The explanation offered for the presence of alkalies in the soils of arid regions is as true here as elsewhere, but these general facts are not applicable in the explanation of the particular cases with which we meet in Colorado agriculture. It is a well known fact, one long since recognized, that the shales of several of the cretaceous groups contain a remarkable amount of these salts, designated by the general term alkali, including sodium, calcium, and magnesium as sulfates, carbonates, and chlorids.

### GENERAL COMPOSITION OF THE ALKALIES.

§ 10. Analyses of incrustations from various parts of the State, and of waters from both ordinary and artesian wells, show the very general distribution of these salts. They also corroborate the observation of their presence in the shales and other rocks which, whatever may have been the origin of the salts, serve at the present time to furnish the alkalies to the waters percolating through them. The following figures, representing the general composition of the alkali, will serve to illustrate the general application of the assertion. An incrustation from the College Farm showed:

| | | |
|---|---|---|
| Calcic sulfate | 25.451 | per cent. |
| Magnesic sulfate | 19.798 | per cent. |
| Sodic sulfate | 41.748 | per cent. |

The ground water from about five feet below the surface yielded an abundant residue, composed of:

| | | |
|---|---|---|
| Calcic sulfate | 35.648 | per cent. |
| Magnesic sulfate | 28.750 | per cent. |
| Sodic sulfate | 11.393 | per cent. |

A surface well, 28 feet deep, yielded water giving a large residue, of which these salts formed 74 per cent., as follows:

| | | |
|---|---|---|
| Calcic sulfate | 15.206 | per cent. |
| Magnesic sulfate | 29.059 | per cent. |
| Sodic sulfate | 29.865 | per cent. |

An artesian well, supposed to tap a water bearing Dakota sandstone and having a depth of 845 feet, furnished a water carrying 79 grains of total solids in each imperial gallon, of which 83 per cent. consisted of these salts, as follows:

| | | |
|---|---|---|
| Calcic sulfate | 12.036 | per cent. |
| Magnesic sulfate | 10.473 | per cent |
| Sodic sulfate | 60.758 | per cent. |

It is evident, not only from observation, but as is also indicated by such figures as these, that it is not at all necessary for the agriculturist to question in regard to the immediate source of the salts included under the general term alkali. They are so abundantly present in the rocks and waters, even in waters from considerable depths, that there is no need to seek further for their supply. The questions relative to their more remote origin and how it happens that the shales and even the sandstones are impregnated with these salts can be left to the geologist without serious inconvenience in studying the questions with which our agriculture has to deal. They are here, and in cases where the drainage of any larger area accumulates in a small basin, alkali salts will be brought together and under proper conditions will appear as an incrustation. This does not take place unless the water plane is at a less distance from the surface than that through which capillarity can raise the water in the particular soil. This was the case in the soil in question, the incrustations accumulating to a maximum thickness of upwards of one half inch. The incrustations being most marked in early summer, but also during the winter when the condition of the weather was favorable.

Relative to the origin of such quantities of sulfates in these rocks and soils, the possible supply is abundant, for throughout the mountain masses we find sulfids disseminated everywhere and we have an almost inexhaustible source of sulfuric acid for the formation of alkali in the gypsum which is so abundant in our Jurassic and other formations.

### THIS STUDY LARGELY A MINERALOGICAL ONE.

§ 11. It is to be understood that throughout this bulletin the term soil is used sometimes to mean all of the factors conducing to make up the unit which is expressed by this term; at others in a much narrower sense, meaning to include only a part of the same.

Most of our analyses, for instance, have to do with only one phase of the subject and that almost exclusively a mineralogical one which may practically be designated as a somewhat indefinite study of the decomposition products of feldspar, principally a red orthoclase. It may be a little humiliating at this juncture to make so uncomplimentary a statement concerning this part of our work, but it is scarcely more. This is very plainly suggested by the results of the mechanical analysis which, as already stated, shows this mineral to be the principal one from which the potash can be derived. The small amount of mica in the soil would, even if the mica were easily attacked and altered, contribute but a very small amount of potash or lime, it being very subordinate in quantity. The analyses of the separate parts of the soil as obtained in the mechanical analysis will be shown to suggest the same fact so forcibly that it amounts almost to absolute proof that in our samples we have to do with an altered feldspar.

### THE EXPERIMENTS COVER TOO SHORT A PERIOD.

What the effect of growing three crops on this soil may have been is scarcely shown by so short a series of experiments; that is, the results are not large enough to be measured by the means at our command. Even if we should confine the effect to the clay this would still be true. This, however, cannot, as we will show, be justly done, for the feldspar certainly yields fresh quantities of potash to the soil. This mineral is so finely divided, or enough of it is, that even the rain water can and undoubtedly does take a perceptible quantity of this compound into solution.

### POTASH IN FELDSPAR AVAILABLE.

§ 12. We shall show by direct experiment that the oat plant, for instance, can appropriate potash from this mineral when it is finely powdered, even in cases in which the mineral is perfectly fresh and the whole work of decomposition has to be done during the period of growth of the plant, perhaps by the roots of the plant itself. The theory of the formation of zeolitic minerals, to serve as the conveyors of the potash, etc., from the more stable minerals to the plant, cannot very well be appealed to, at least as necessary. My experiments do not show that zeolitic compounds are not formed, but they do show that if they are formed, their formation takes place so rapidly that perfectly fresh, but finely pulverized, feldspar becomes an available source of potash in the short period required for the growth of the oat plant. I do not mean to say that finely powdered feldspar will yield potash so rapidly that it will furnish a supply adequate to the production of a crop, but that it will furnish in the aggregate a very considerable quantity of this element. It is a well known fact that this mineral yields potash to water and it was to be expected that growing plants might obtain some potash from this source, but my experiments show that this plant may perfect its growth, obtaining all of its potash from the pulverized feldspar.

§ 13. This fact is of great importance to our Western agriculture, especially to the agriculture of the eastern slope of the Rocky Mountains and eastward to the State line, as the irrigable lands are composed largely of granitic materials and consequently contain a more or less considerable quantity of feldspar, whose decomposition yields, slowly it may be, but a continuous supply of this very important compound. The partially altered mineral possibly presents a greater degree of resistance to further decomposition than the fresh mimeral does to the first attack, but this will affect only the rate of the supply, for we know that this mineral eventually suffers complete decomposition. These soils, or mixtures of minerals, quartz, feldspar and mica, are well preserved because our climatic conditions have not been favorable to their decomposition, either directly or through the decay of organic matter. The rate of change under more favorable conditions, those of irrigation with an increase of vegetable matter, may be more rapid, but it will still be comparatively slow; not too slow, however, to make its results a factor in the supply of potash for our cereal crops.

§ 14. A question arises in this connection relative to the course which the decomposition of the feldspar takes, and whether an experiment with powdered feldspar is comparable with the conditions which prevail in the soil. There is no question but that they are not wholly so. The decomposition may go on either more rapidly or less rapidly in the soil than in the experiment with a mixture of sand and feldspar in boxes. Still the results are, in a measure, comparable. The soil contained from 16 to 28 per cent. of dust, the particles of which have a diameter of less than 0.01 millimeter, and while, as previously intimated, the original feldspar present may have already been so changed that its further decomposition may be somewhat slower than at some previous stage of its history, it has not been removed from all further action of the solutions in the soil, the plant roots and other agents.

In experimenting with the feldspar, the whole of it was reduced to powder, whose largest grains were less than one millimeter in diameter, and of which rather more than 33 per cent., by weight, consisted of particles of less than one quarter of a millimeter in diameter. The feldspar was pulverized to render it more readily attacked, and to reduce its particles to a size comparable with the size of the finer soil grains.

### FELDSPAR A SOURCE OF HYDROUS SILICATES.

§ 15. The water in the soil also shows that such changes are going on continuously, for they are constantly removing salts in solution, the supply of which is, in part at least, maintained by the decomposition of the constituent minerals of the soil. If there were no such supply of these salts, they ought to have diminished in quantity to a very small fraction of that which we now find. The formation and continuous presence of highly reactive, hydrous silicates within the soil may be accepted as established, but back of this, as well as of that of clay, whether kaolinitic or colloidal, are the decompositions of which these compounds are themselves but products. In the case of the soils in question, the original minerals whose changes have furnished the materials for these zeolitic compounds are preeminently the feldspars of the granites of the front range. Traces of igneous rocks are found, but their part in the formation of these soils is so subordinate that they may be neglected. That the ground waters, already rich in salts, participate in producing these changes is very probable. The uniform presence of potash salts in the ground water is presumably due in part to this fact. The elimination of potash from the soil in the form of nitre, potassic nitrate, will account for the presence of some, but not for the whole, of the potash present in the ground water. The presence of silicic acid in all of the water, amounting in some instances to about 2 per cent. of the total solids, is likewise suggestive of the decomposition of silicates, yielding, among other products, new silicates soluble in water. The silicic acid present in the water analyses, which will subsequently be given, was in solution either as hydrated silicic acid or in the form of soluble silicates.

A very striking instance of the presence of silicic acid in water came under my notice a few years ago. The water was a very excellent spring water, free from sediment, limpid, and had a temperature of 53° F. The silicic acid present amounted to 25 per cent. of the total solids held in solution. I do not know whence this silicic acid was derived, but most probably from the decomposition of some feldspar, as potash and soda were the next most abundant constituents of the residue obtained from the water. The chemical changes producing such a solution as this in a spring water are quite sufficient, even though they may be modified in many ways, to account for the silicic acid found in the residues obtained from ground waters.

### SOME SALTS ARE FORMED IN THE SOIL.

§ 16. We cannot distinguish between the salts which have been dissolved out of adjacent localities and brought by the flowing waters into the area where it is found, and those which have been formed in the latter soil. In the former case they may contribute to bring about new changes, in the latter they will be products of the changes ordinarily going on in that soil, and aid in giving distinctive properties to it. These would remain if the others should be eliminated.

§ 17. The relative amount of magnesic salts which are present in the ground waters before and after the soil has been cultivated, also before and after the application of manure, indicate that there is a series of reactions taking place which result in eliminating these salts as end products. The growing of crops, the cultivation and irrigation of the soil, also the application of manure, accelerate these changes. The readiness with which these reactions take place, especially if they be beneficial to the crop, must, to a considerable extent, be a measure of the soil's fertility.

### THE BIOLOGY OF THE SOIL NOT STUDIED.

§ 18. The soil is not only the theater of a wide range of chemical reactions, some dependent upon and some independent of the living organisms present, but it is also the home of an abundant microscopic life, constituting a veritable world of itself.

§ 19. The biological conditions of the soil ought, in this study, to have been taken up with thoroughness, but it has been impossible. We will present the results obtained by such study as we have been able to devote to the soil in the following pages.

§ 20. The purely agricultural features of this study have already been given in Bulletins 46 and 58. These bulletins have treated exclusively of the crops grown on the soil, especially of the effects of the alkali on the growth and ripening of the plant, on the amount of ash constituents taken up, etc. In this bulletin we shall treat of the soil, and in a subsequent one of the ground waters, the irrigation water and its changes.

### THE PHYSICAL CHARACTER OF THE SOIL.

§ 21. Beginning at the west end of the plot the soil is a light loam. This passes into a paludal soil rich in alkali, succeeded by a gravelly, clayey soil, which has resisted treatment to a greater extent than any other portion of the plot. The most eastern section of the plot is the lowest, the wettest, and, judging by the abundance of the salts which effloresce, the most strongly alkalized one. The extreme western section is the only one in which there is a subsoil within six feet of the surface. The character of the eastern most section was that of a very tenacious, alkalized clay, which, when moulded to a form and dried, became exceedingly hard. It was a most unpromising soil to attempt to do anything with. The plot has a slope to the eastward of about four feet in 600. There is a stratum of coarse sand and gravel underlying the whole of the plot at a depth of about six feet. The surface is fairly even, with a slight depression running diagonally from near the southwest corner to the north side, a little west of the centre.

### PREPARATION OF THE SAMPLES.

§ 22. Six samples of this soil were taken in the spring of 1897, before it was plowed for the planting. These samples were taken with care to obtain samples representing the soil. Sections 8″×8″×10″ were cut out and prepared for analysis. These sections were dried, all lumps being broken by hand from day to day as they became dry enough to be rubbed to pieces in this manner. When drier, and too hard to be so manipulated, they were rubbed in an iron mortar, the mortar being filled so full that pulverization did not take place. In order to be able to study the rock fragments still remaining in the samples, they were passed through sieves from one quarter inch to one twenty-fifth inch mesh. All that passed through the one twenty-fifth inch or one millimeter mesh, was preserved as the sample of fine earth. The coarser portions, six in number, were thoroughly washed and their weight and character determined. The samples were designated by the letters A, B, C, D, E and F. The successive parts are designated by the subscript figures 1, 2, 3, etc.

### SAMPLE A.

§ 23. This sample was taken from the east end of the plot, 40 feet east of well A, the worst section of the plot. .. The sample was divided into the following parts:

| *Parts.* | *Meshes to the Square Inch.* | *Character of the Fragments.* | *Per Cent.* |
|---|---|---|---|
| $A_1$ | 4 | Quartz, granite, mica, limestone, feldspar | 0.68 |
| $A_2$ | 9 | Quartz, granite, brown sandstone, limestone, feldspar | 1.17 |
| $A_3$ | 36 | Quartz, granite, mica, oxid of iron, limestone, feldspar | 2.19 |
| $A_4$ | 144 | Quartz, granite, iron oxid, limestone, feldspar | 4.35 |
| $A_5$ | 196 | Quartz, mica, feldspar | 1.92 |
| $A_6$ | 625 | Quartz, mica, iron oxid and feldspar | 6.31 |
| | | Fine earth | 83.38 |

### SAMPLE B.

§ 24. This sample was taken 50 feet west and two feet north of well A. This sample is from the edge of the gravelly, clay knoll, on the north side of the plot, and east of the centre:

| *Parts.* | *Meshes to the Square Inch.* | *Character of the Fragments.* | *Per Cent.* |
|---|---|---|---|
| $B_1$ | 4 | Quartz, brown sandstone, mica, feldspar | 4.54 |
| $B_2$ | 9 | Quartz, brown and red sandstone, mica, feldspar | 3.40 |
| $B_3$ | 36 | Quartz, brown and red sandstone, iron oxid, feldspar | 6.39 |
| $B_4$ | 144 | Quartz, brown and red sandstone, iron oxid, mica, feldspar | 6.83 |
| $B_5$ | 196 | Quartz, mica and feldspar | 3.14 |
| $B_6$ | 625 | Quartz, mica, feldspar | 11.95 |
| | | Fine earth | 63.75 |

### SAMPLE C.

§ 25. This sample was taken 45 feet west and three feet north of well B. This sample is from the eastern edge of the depression running diagonally across the plot and western edge of gravelly knoll.

| Parts. | Meshes to the Square Inch. | Character of the Fragments. | Per Cent. |
|---|---|---|---|
| $C_1$ | 4 | Quartz, granite, feldspar | 13.77 |
| $C_2$ | 9 | Quartz, granite, limestone, iron oxid, feldspar, red and brown sandstone, mica | 6.63 |
| $C_3$ | 36 | Quartz, granite, limestone, sandstone, mica, feldspar | 9.78 |
| $C_4$ | 144 | Quartz, mica, limestone, sandstone, feldspar | 7.53 |
| $C_5$ | 196 | Quartz, mica, limestone, feldspar | 2.63 |
| $C_6$ | 625 | Quartz, mica, feldspar | 9.08 |
| | | Fine earth | 50.58 |

### SAMPLE D.

§ 26. Sample taken 25 feet west and three feet north of well C. This sample represents the low portion of the west half of the plot. It is quite wet and strongly alkalized.

| Parts. | Meshes to the Square Inch. | Character of the Fragments. | Per Cent. |
|---|---|---|---|
| $D_1$ | 4 | Quartz, granite, feldspar | 1.50 |
| $D_2$ | 9 | Quartz, red and brown sandstone, limestone, feldspar | 0.67 |
| $D_3$ | 36 | Quartz, granite, sandstone, limestone, feldspar | 1.86 |
| $D_4$ | 144 | Quartz, sandstone, limestone, iron oxid, feldspar | 2.80 |
| $D_5$ | 196 | Quartz, limestone, mica, feldspar | 2.08 |
| $D_6$ | 625 | Quartz, mica, feldspar | 8.81 |
| | | Fine earth | 82.27 |

### SAMPLE E.

§ 27. Sample taken three feet west and three feet north of well D. This sample represents the western end of the plot.

| Parts. | Meshes to the Square Inch. | Character of the Fragments. | Per Cent. |
|---|---|---|---|
| $E_1$ | 4 | Quartz, granite, feldspar | 0.71 |
| $E_2$ | 9 | Quartz, granite, feldspar | 0.29 |
| $E_3$ | 36 | Quartz, granite, limestone, sandstone, iron oxid, feldspar | 1.25 |
| $E_4$ | 144 | Quartz, mica, limestone, iron oxid, feldspar | 3.38 |
| $E_5$ | 196 | Quartz, mica, limestone, feldspar | 2.99 |
| $E_6$ | 625 | Quartz, mica, feldspar | 11.37 |
| | | Fine earth | 80.01 |

### SAMPLE F.

§ 28. This sample is the subsoil corresponding to sample E.

| Parts. | Meshes to the Square Inch. | Character of the Fragments. | Per Cent. |
|---|---|---|---|
| $F_1$ | 4 | | 0.00 |
| $F_2$ | 9 | | 0.00 |
| $F_3$ | 36 | Quartz, limestone, feldspar | 0.03 |
| $F_4$ | 144 | Quartz, limestone, feldspar | 1.58 |
| $F_5$ | 196 | Quartz, limestone, feldspar | 1.84 |
| $F_6$ | 625 | Quartz, limestone, feldspar | 9.34 |
| | | Fine earth | 87.21 |

## MECHANICAL ANALYSIS OF THE "FINE EARTH."

§ 29. The beaker elutriation of the fine earth gave the following results:

TABLE I.—MECHANICAL ANALYSIS OF THE FINE EARTH.

| SAMPLE. | Hygroscopic Moisture. | Temperature of Absorption. | Water Capacity. | Coarse Sand. 1.0 to 0.5 mm. | Medium Sand. 0.5 to 0.25 mm. | Fine Sand. 0.25 to 0.05 mm. | Silt. 0.05 to 0.01 mm. | Dust. Less than 0.001 mm. | Clay by Difference. | Ignition. |
|---|---|---|---|---|---|---|---|---|---|---|
| Soil A | 6.40 | 15° | 51.05 | 4.459 | 5.392 | 26.078 | 19.527 | 27.878 | 8.314 | 8.351 |
| Soil B | 4.50 | 15° | 36.50 | 8.114 | 10.147 | 35.593 | 12.386 | 23.653 | 4.582 | 5.543 |
| Soil C | 4.20 | 15° | 44.22 | 7.318 | 6.940 | 20.518 | 20.828 | 27.633 | 7.876 | 8.887 |
| Soil D | 5.90 | 15° | 40.54 | 6.254 | 7.197 | 25.894 | 24.748 | 21.704 | 6.013 | 8.190 |
| Soil E | 3.40 | 15° | 36.84 | 7.070 | 9.227 | 29.947 | 25.573 | 16.642 | 3.534 | 8.007 |
| Soil F | 3.50 | 15° | 42.34 | 6.380 | 7.409 | 23.736 | 30.604 | 19.488 | 5.552 | 7.673 |
| Loess Soil. Weld Co. | ...... | ..... | ....... | 1.172 | 3.737 | 45.707 | 27.721 | 10.565 | 5.217 | 5.881 |
| Loess Soil. Larimer Co. | ...... | ..... | ....... | 0.965 | 2.073 | 24.451 | 49.714 | 11.797 | 4.567 | 6.433 |
| Red Soil. Clay Soil. Red Beds. | ...... | ..... | ....... | 4.411 | 11.872 | 27.943 | 31.592 | 13.793 | 4.600 | 5.789 |

## THE MINERALOGICAL CHARACTER AND SOURCE OF THE SOIL PARTICLES.

§ 30. The sand grains in the different samples consisted of quartz, feldspar and some flakes of mica. The quartz grains show plainly the deposition of oxid of iron upon their surfaces, in checks and depressions in the grains. The deportment of the sand, and more particularly the still coarser portions, warns us that we cannot conclude that the sand particles owe their origin to the red beds, because of their color after ignition, for there is enough organic matter coating the grains to cause blackening upon heating, and this may account for the presence of the iron oxid which becomes evident upon igniting the sands. There is nothing distinctive enough, so far as I have observed, about the sand grains to justify one in asserting that they did or did not come from the juratrias, or Dakota sandstones, or are directly due to the breaking up of the granites. The presence of so large an amount of feldspar and mica, neither of which is present in the sandstones of these formations in such quantity, is strong proof that practically the whole mass is derived directly from the rock masses of the mountains which lie immediately west of us, and consists of granites, gneisses and mica schists.

§ 31. While I believe myself justified in making the statement that the most of the rock material of this soil came directly from the mountain masses in geologically recent times, I am fully aware that the disintegration of the red sandstones, and to a less extent the conglomerates of the red beds, could give rise to a very similar mixture of rock fragments. The following facts show this plainly. A sandstone belonging to the upper part of the Upper Wyoming, of loose texture and easily disintegrated by soaking and judicious rubbing, without any grinding up of its particles, gave me the followitg mechanical analysis:

Sand grains having a diameter greater than two millimeters, 1.40 per cent.; greater than one millimeter, 26.80 per cent.; less than one millimeter, 62.70 per cent.; cementing material, oxid of iron, calcic carbonate, etc., 9.10 per cent. The sand grains were principally quartz, but there were some grains of feldspar and a few flakes of mica. In regard to the fineness of the particles, it will be noticed that practically 63 per cent. of the mass of the sandstone was as fine as that division of the soil designated "fine earth," and that this percentage is as great or greater than that of the fine earth in two of our soil samples. The alkalies in this sandstone were determined and found to amount to 1.30 per cent. of the sandstone; potash constituting 1 per cent., and soda three tenths of 1 per cent. The cementing material, mostly calcic carbonate and oxid of iron, contained a small amount of these constituents, potash 0.025 per cent., soda 0.053 per cent., calculated on the sandstone, not on the weight of the cementing matter. The alkalies were also determined in a sandstone from the Lower Wyoming, and found to equal 2.563 per cent. of the sandstone; potash 0.924 per cent., soda 1.639 per cent. The potash in each of these cases amounts to about 1 per cent., and is contained almost wholly in the sand grains, among which, especially among the larger ones, feldspar grains are easily recognizable. These sandstones do give rise to a soil whose elutriation would yield a mixture of sand grains somewhat similar to that with which we have to do in this study. The characteristics of the soil formed by the disintegration of these sandstones are so markedly different from those of the one we are considering, that they are not even suggested as the possible source of the material, except by the most thorough washing of the soil formed from them.

§ 32. The statements relative to the mineralogical character of the different classes of soil particles are applicable to all of the soils which I have analyzed or examined with care, whether close to the mountains or as far east as the State line, excepting the soils of the valley lying between the hogback formed by the Dakota sandstone and the mountains proper. This area, corresponding to the outcrop of the red beds, is not wholly covered by this granitic soil. There are doubtlessly some sections where the surface soil is derived from younger formations, the particles of which have not been transported from the mountains by the streams or waters which have given the country its present contour, but are disintegration products of formations composed of material similar to that brought from the mountains by the streams of later times.

The particles of more than 0.5 millimeters diameter are for the most part rounded, but this is not the case with those less than .25 millimeters, nearly all of which are sharply angular.

§ 33. It may appear to many, especially to such as have an acquaintance with the occurrences of loess and other formations of the plains, the mineralogical constituents of which are often identical with those given for these soils, that the latter, like the former, may be the product of other disintegrations than that of the granites of the Colorado range. There is nothing in their composition to preclude their having been derived from some other source. Their geographical distribution makes it probable that material similar to this composing our soils has been derived from other mountains than those lying near to us. It seems reasonable, however, to assume that the near and very extended range has furnished essentially all of the material going to make up these soils. There may be a doubt entertained that the quartz, feldspar and mica given in the preceding table were derived from the present mountains, but there can be no question regarding the source of the fragments of red and brown sandstones, or of the impure limestone; these are the products of the disintegration of the red beds and of the Fort Benton limestone.

## SOIL COMPARED WITH LOESSIAL SOIL.

§ 34. There is given in the table of mechanical analyses, one of a loessial soil from Weld county. This soil, according to the mechanical analysis, has a very different composition from the soils given above. It is characterized by a high percentage of fine sand and low percentages of dust and clay, but mineralogically the sand and coarser parts are the same as in the other soils, *i. e.*, quartz, feldspar and mica. The mica, though still subordinate in quantity, is more abundant in the loessial soil than in the others. It seems to be a general rule that the farther back from the river we get, or higher up on the plains, the greater is the percentage of fine sand present in the soil.

§ 35. I have not attempted to determine the ratio between the grains of feldspar and quartz in these soils, but others have determined this ratio in the loess, for which the approximate determination is given as: Quartz, 40 per cent.; feldspar, 50 per cent.; other constituents, 10 per cent.* The minerals making up the other 10 per cent. were, in the case of the Weld county loessial soil, mica, magnetic oxid of iron, etc. I have not determined, by actual count, the grains of quartz and feldspar, but my judgment is that there is more quartz in the sands that I have separated from these soils than is indicated by the percentage given in the analysis quoted, viz., 40 per cent. It is to be expected that the mechanical composition of soils will vary from place to place, and yet the table shows a greater agreement than we would expect; the sample of loessial soil from Weld county and of loess from Larimer county being the only ones which show wide deviations in the percentage of any class of soil particles. Not only the mineralogical, but also the chemical examination of these soils, indicate a rather uniform composition, though the samples were taken from widely separated localities. By chemical analysis is here meant the analysis of the whole mass, a mass analysis, and not a soil analysis as it is made for agricultural purposes.

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* Emmons' Geology of the Denver Basin in Colorado, p. 262.

§ 36. Dr. S. F. Emmons, writing of the loess in the "Geology of the Denver Basin in Colorado," says that it contains in all cases a large proportion of sand, separable by washing, whose grains are usually under a millimeter, but rarely less than a tenth of a millimeter in diameter. The mechanical analyses of the loessial soils show 43 and 64 per cent. of the mass to have a diameter of less than five one hundredths of a millimeter. The mechanical analysis of this soil shows 47.40 per cent. of material, the clay not included, whose grains have a diameter of less than one tenth of a millimeter, and which differ from the coarser portions only in the degree of their comminution. The loessial soils given agree in having high percentages of fine sand and silt, and lower percentages of dust and clay than ordinary soils; but our results do not agree with Dr. Emmons' observation that the grains of sand in loess are rarely less than one tenth of a millimeter in diameter.

### SIMILARITY OF THE PARTICLES AND COMPOSITION OF SOILS.

§ 37. The fine sands are, in every case, much more angular than the coarser, due to the manner in which the water has effected their transportation, the larger having been rounded by rolling or by attrition while in suspension. The loessial soils show this characteristic as markedly as the other soils examined. There is so great a similarity in the mineralogical composition of our soils, though they vary in appearance, that it is a matter of some surprise that they should differ so extremely in properties. The chemical analysis of the soils, mass analysis, does not change this phase of the matter at all. The following analyses of samples taken from rather widely separated localities, may serve to illustrate this:

## TABLE II.—MASS ANALYSES OF SOME SOILS.

| | Prairie Soil, South of Agricultural Hall. Surface. | Soil A. Taken 10″ deep. | Loessial Soil. Weld County. 21½″ deep. | Loessial Soil. Larimer County. 6 ft. from top. | Loess. Cheyenne, Wyo.* |
|---|---|---|---|---|---|
| Silicic Acid | 69.356 | 64.745 | 72.550 | 67.836 | 67.100 |
| Sulfuric Acid | 0.041 | 0.827 | 0.023 | 0.025 | ......... |
| Carbonic Acid | 0.016 | 1.208 | 0.368 | 0.888 | 3.670 |
| Chlorin | 0.006 | 0.014 | Trace. | 0.022 | ... ..... |
| Phosphoric Acid | 0.466 | 0.112 | 0.331 | 0.411 | 0.110 |
| Potash | 2.248 | 2.295 | 2.479 | 2.497 | 2.680 |
| Soda | 1.215 | 1.184 | 1.498 | 1.311 | 1.420 |
| Lime | 1.645 | 2.789 | 1.075 | 2 481 | 5.880 |
| Magnesia | 1.412 | 1.819 | 1.245 | 1.740 | 1.240 |
| Ferrous Oxid | ......... | ..... .. | ........ | ........ | 0.310 |
| Ferric Oxid | 5.424 | 4.475 | 4.420 | 5.255 | 2.520 |
| Aluminic Oxid | 11.338 | 11.717 | 10.754 | 11.418 | 10.260 |
| Manganic Oxid (br) | 0.160 | 0.200 | 0.239 | 0.109 | ......... |
| Moisture at 110° C | 2.981 | 3.296 | 2.595 | 3.569 | ......... |
| Ignition | 4.044 | 5.402 | 2.311 | 2.287 | 5.099 |
| Sum | 100.352 | 100.080 | 99.888 | 99.849 | 100.280 |
| Oxygen Equivalent to Chlorin | 0.001 | 0.003 | ........ | 0.005 | ......... |
| Total | 100.351 | 100.077 | 99.888 | 99.844 | 100.280 |

* Analysis by Eakin's Geology of the Denver Basin in Colorado, p. 263.

I have chosen the sample of loess from Cheyenne because this is probably more nearly comparable to mine than any other at my disposal, and the locality is nearer by thirty miles than that from which the next nearest sample was taken. The sample marked loess from Larimer county was taken at a point about seven miles from the place where the sample soil A was taken. The most marked variations in the composition of these samples are, the sulfuric acid of the soil A, the carbonic acid and lime of the loess from Cheyenne. The sulfuric acid in the soil was probably present as calcic sulfate or sodic sulfate, forming a part of the "alkali" present in the soil. The carbonic acid and lime in the Cheyenne loess was doubtlessly present as calcic carbonate. This is of common occurrence in this formation; is very variable, and is not essential. With these exceptions, the causes of which are usually discernible without the aid of chemical analysis, or even a magnifying glass, these soils agree as closely as samples taken within a few feet of one another might agree, and suggest a common origin for wide areas of our surface soils.

The alkalies are lower than one would expect, judging from the number of feldspar particles which are present, and the ratio of the soda to the potash is high, as the feldspar recognizable is very predominantly orthoclase. The silicic acid is lower than the apparently large number of quartz grains present would suggest. The orthoclase contains, in round numbers, 66 per cent. of silicic acid, while the average percentage of this acid in these soils is 68.6 per cent., which seems lower than the macroscopic examination suggests.

### PORTIONS OF FINE EARTH EXAMINED.

§ 38. The loess from Cheyenne was not examined further, nor was the loessial soil from this county, but the soil A was. The fine sand, with particles from 0.25 to 0.05 millimeter in diameter, the silt, the dust and the clay were each analyzed with the following results:

TABLE III.—ANALYSES OF PORTIONS OF "FINE EARTH" OF SOIL A. SAMPLE TAKEN TEN INCHES DEEP.

| | *Fine Sand.* | *Silt.* | *Dust.* | *Clay.* |
|---|---|---|---|---|
| Silicic Acid | 82.024 | 69.247 | 58.204 | 40.389 |
| Sulfuric Acid | 0.017 | 0.014 | 0.100 | 7.060 |
| Potassic Oxid | 1.914 | 2.711 | 3.166 | 3.000 |
| Sodic Oxid | 1.926 | 1.851 | 1.323 | 3.134 |
| Ferric Oxid | 3.383 | 5.425 | 9.109 | 7.113 |
| Aluminic Oxid | 6.737 | 13.018 | 19.078 | 14.607 |
| Calcic Oxid | 1.746 | 1.488 | 1.480 | 6.059 |
| Magnesic Oxid | 0.777 | 1.519 | 2.648 | 3.982 |
| Manganic Oxid (brown) | 0.150 | 0.250 | 0.190 | 0.168 |
| Moisture and Organic Matter | 0.750 | 4.118 | 3.980 | 14.668 |
| Total | 99.424 | 99.631 | 99.278 | 100.180 |

The coarser parts of the soil were not analyzed, for the reasons that they are comparatively small in quantity and, on account of the large size of their particles, are not subject to those actions which liberate plant food to any considerable extent. It might have been better for a favorable presentation of results had we analyzed them, but there was so little to be gained that we did not deem it worth the work. This table shows a very decided difference in the composition of the parts separated by washing the soil. We have no basis of comparison with the loess and other soils. The series stands alone, but the results that it exhibits are so pronounced and so similar to what we would expect that we have little hesitancy in accepting it as proven that there is an accumulation of the potash in the finer portions of the soil, and a diminution of the silicic acid.

### PROBABLE COURSE OF CHEMICAL CHANGES IN SOIL MASS.

§ 39. We have here probably a rough presentation of the course of the chemical changes which take place in the transformation of a mass of rock fragments into true soil. The decomposable minerals, feldspar and mica, very subordinate in this case, are so acted upon that new minerals, having less silica but more alumina and possibly alkaline earths, are formed. The high percentage of lime in the analysis of the clay is almost certainly due to an admixture of gypsum. It is scarcely possible, owing to the manner of preparation, that the higher percentage of magnesic oxid can be attributed to a similar cause. In regard to the potash, which is even higher in the dust than in the clay, though the experienced analyst will be inclined to consider them the same, there may be a question as to the manner in which it is present. This arises from the knowledge of facts obtained from other experiments and not from the analyses. The testimony of the latter is, and it is in perfect harmony with what we know of the deportment of soil masses, that in the extremely small particles of the soil there is a tendency toward enrichment in potash. The indications of the analyses, contrary to the impressions of the writer, indicate that the maximum of this concentration is reached in the portion designated as dust, a portion whose individual particles have a diameter of less than 0.01 millimeter, or less than one twenty-five hundredths of an inch, and which constitutes 27.87 per cent. of this soil. The clay, which is still very much finer, contains, in this case, essentially the same percentage of potash, but constitutes only 8.31 per cent. of the soil. In this instance the dust and not the clay is the potash carrying silt-constituent of the soil.

§ 40. The fine particles of the dust and clay are probably not wholly composed of fine residual parts of the minerals originally composing the soil mass, but are to a greater or less extent made up of newly formed particles of precipitates, or at least of newly formed minerals, which may adhere tenaciously to the fine residual grains or form independent little aggregates which, being disintegrated by the washing of the soil, are obtained in the form of clay.

### ANALYSES OF PARTS OF FINE EARTH SHOW NO DEFINITE RATIOS.

§ 41. Little can be said in regard to the ratios existing between the various chemical constituents as shown in the preceding analyses. There is, for instance, no clear and definite relation between the potash and soda, iron oxid and alumina, alkalies and alkaline earths. The iron is, taken roughly, equal to one half of the alumina. This holds true for soil A, the parts of the soil separated by washing, and of the Larimer county loess. I am inclined to think that this is an accident, in spite of its occurring in each of these six instances. It is not the case in the Cheyenne loess, and extraction with hydrochloric acid shows it to be almost wholly soluble in this agent. Macroscopic observation, especially after ignition, shows the sand grains to be coated to a greater or less extent with this substance, oxid of iron. It does not appear as red oxid of iron on the grains before ignition, but becomes evident after. This is well seen in the color of the mass before and after ignition. This suggests the existence of hydrates of iron or organic compounds, but the loss on ignition is so small and irregular, bearing in its quantity no relation to that of the iron, that the organic compounds, if any, are very small in amount. There seems to be, as we shall see later, but a small amount of iron present in the form of a silicate insoluble in hydrochloric acid, certainly not more than may be present in a perfectly fresh feldspar. This would still be the case if the quartz sand were all deducted or considered as carrying no iron whatever. The portion soluble in hydrochloric acid, on the other hand, is rich in iron. The total loss on ignition is not unusually large, and a portion of this is water retained at the temperature of 110° C, probably in the form of hydrated oxid of iron.

### SOLVENT ACTION OF HYDROCHLORIC ACID ON THE SOIL.

§ 42. The portion of these soils dissolved or decomposed by hydrochloric acid, sp. gr. 1.115, upon digestion for five days, varied from 30 to 50 per cent. The amount dissolved certainly depends upon the character of the substances present in the samples, but in this respect our samples are very uniform, containing essentially the same mineralogical components. The variation in the amount dissolved depends upon other conditions, principally upon the fineness of the soil particles, and the particular degree of their decomposition. The former condition is the more important, as the latter one is largely dependent upon it. This is quite clearly seen upon a comparison of the mechanical analyses of these samples, taking the particles having a diameter greater than 0.05 millimeter as one group, and those of less diameter as another group. The amount dissolved under the convential conditions, HCl., sp. gr. 1.115, and five days digestion on water bath, varies, but not closely, with the ratio of these two groups, into which every soil can be divided. In other words, it is the very fine particles of the soil which yield to the hydrochloric acid the elements of plant food found in the solution. This is unquestionably the case in the soil, as well as in the analysis. The decomposition of the minute particles of the minerals will take palce more slowly in the soil solutions than in the hydrochloric acid, but the order in which they will be attacked is the same, the finest first.

### RESULTS OF CHEMICAL ANALYSES NOT COMPETENT CRITERIA.

§ 43. The chemical analysis does not give us a good criterion by which to judge of the virtues of a soil. It may not follow the same course of decomposition that takes place in the soil, and it certainly extends too far, that is, we can not say how long it would take to effect the same amount of change by the soil agents, as is effected by an acid solution and heat during the five days digestion, or by strong acid in ten hours.

### THE SAMPLES ANALYZED.

§ 44. The samples and the manner in which they were taken have already been described. Two sets of samples were taken, one on May 13, and another on October 20, 1897. These samples were taken from the same parts of the plot, in order to make them agree as nearly as we could. We hoped that the earlier samples would enable us to ascertain the composition of the soil, the later ones to determine, if possible, the effects of cultivating, irrigating, and cropping it. The crop grown was sugar beets. The work done on the crop, both in the field and laboratory, is recorded in Bulletin 46. The whole crop, both roots and tops, had been removed before we took the samples in October.

### WATER RECEIVED.

§ 45. The rainfall was about 9 inches. The amount of irrigation water used in the two irrigations given was not measured, but was estimated by an experienced man to be about 8 inches, or approximately 17 inches in all. The drainage of this plot of ground is not good, and we now know that it receives water from the west as sub-irrigation. This we did not know at the beginning of our experiment, or rather we supposed that we were protected from this interference by a ditch and a drain. The water plane during this season was higher than during the succeeding season of 1898, but this, I think, was due in part to greater rainfall and more frequent irrigation. Two factors enter here which are wholly undetermined, the upward movement of the water-soluble salts in the soil, due to evaporation from the surface, and the salts removed by drainage. The former was made as low as our conditions would permit, by keeping the surface soil well stirred by frequent cultivations, and by the luxuriant growth made by the beet tops. I do not know how much either of these agencies accomplished during the season, nor do I know that any attempt has been made to determine the amount of evaporation from the surface of the soil at this place under any conditions. The amount of drainage from this plot was sufficient to lower the water table, after it had been raised by irrigating the plot, two feet in eleven days. In this case, the adjoining land had received no irrigation, and the rise in the water plane was purely local.

§ 46. The draining out of the water may have been due as much to a spreading of the water over a larger area, as to draining out. Under such conditions as the early summer season presented, the fall of the water plane in this plot took place at the rate of one foot in thirty days. I would have assumed this to be the rate of drainage out of this area, had we not demonstrated, much against our will at the time, that there is a flow of water from the west into our plot, and the fall of one foot in thirty days is simply the excess of the drainage out of the area over that into it.

### DEPORTMENT OF SOIL WITH WATER SHRINKAGE INCLUDED.

§ 47. I have stated twice that one characteristic of this soil is its retentiveness of moisture. I do not mean by this statement that it will refuse to give up a larger percentage of moisture than other soils, when exposed to drying out in the air or subjected to drought, but that excessive water is given up slowly, and also that when it dries it shrinks and becomes very hard, which is true of many soils in this State.

§ 48. I made two experiments to determine the rate at which this soil dries after being saturated with water, and also to determine the loss of volume due to shrinkage.

These samples deported themselves very differently. The sample of soil A, placed in a cylindrical box, showed moisture on the surface in seven minutes after the perforated bottom of the box was placed in water, but the soil had not become saturated at the expiration of four and one-quarter hours, and was permitted to stand in contact with the water over night. The sample of soil D, on the other hand, did not show moisture on the surface until forty-five minutes after it was placed in contact with the water, but was saturated in one and one-quarter hours. Soil A required for saturation 18.18 grams of water, and lost in eleven days 17.78 grams; D required 16.62 grams for saturation, and gave up 16.20 grams in eleven days. The shrinkage was the same in both cases, 28 per cent. of the original volume. The cylinders were filled and shaken down to make the soil compact. The loss for each twenty-four hours, up to the end of the seventh day, is given in the following table, together with that for pulverized feldspar, which was used for the sake of comparison. The feldspar had been pulverized so that its particles approached those of the soil as nearly as possible in size. The volumes were the same. It will be born in mind that the soil contains humus, clay, salts, etc., while the feldspar does not. The feldspar showed moisture in one minute after being placed in the water. One sample was saturated in ten and the other in twenty minutes. This is a very pronounced difference, the soils requiring 75 and upwards of 255 minutes for their saturation. The feldspars required for saturation 8.94 and 7.39 grams of water respectively, the soils, 18.18 and 16.60 grams.

TABLE IV.—RATES AT WHICH THE SOILS GAVE UP WATER.

| | *Soil A.*<br>*Grams.* | *Soil D.*<br>*Grams.* | *Feldspar.*<br>*Grams.* | *Feldspar.*<br>*Grams.* |
|---|---|---|---|---|
| Water given up in first 24 hrs | 3.58 | 3.10 | 2.06 | 2.00 |
| Water given up in second 24 hrs | 2.45 | 3.00 | 2.52 | 2.42 |
| Water given up in third 24 hrs | 2.47 | 2.45 | 1.99 | 1.95 |
| Water given up in fourth 24 hrs | 2.33 | 2.40 | 1.85 | 0.97 |
| Water given up in fifth 24 hrs | 2.40 | 2.40 | 0.06 | 0.01 |
| Water given up in sixth 24 hrs | 2.10 | 1.60 | .... | .... |
| Water given up in seventh 24 hrs | 1.20 | 0.35 | .... | .... |

The experiment with the soils was continued for four days longer, but the loss was comparatively slow. The feldspar showed no shrinkage. The temperatures at which these experiments were made were 15°–16° C. for the soil samples, and 16°–17° for the feldspars.

### ANALYSES OF HYDROCHLORIC ACID SOLUTIONS OF THE SOILS.

§ 49. The description of these samples has been given in a preceding paragraph, and the method of analysis was a conventional one, digestion with hydrochloric acid, sp. gr. 1.115, on a water bath for five days.

## TABLE V.—ANALYSES OF SOILS. GENERAL SAMPLES.

| | A. May 13, 1897. | B. May 18, 1897. | C. May 13, 1897. | D. May 13, 1897. | E. May 13, 1897. | F. May 13, 1897. | A. Oct. 20, 1897. | B. Oct. 20, 1897. | C. Oct. 20, 1897. | D. Oct. 20, 1897. | E. Oct. 20, 1897. | F. Oct. 20, 1897. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Insoluble | 53.470 | 70.065 | 58.951 | 53.617 | 62.572 | 54.262 | 50.228 | 70.756 | 51.047 | 56.092 | 61.871 | 53.572 |
| Silicic Acid, Soluble | 17.875 | 11.379 | 17.449 | 18.662 | 12.918 | 12.126 | 21.346 | 11.587 | 20.287 | 17.926 | 13.552 | 10.671 |
| Sulfuric Acid | 0.827 | 0.488 | 0.508 | 0.921 | 0.517 | 0.529 | 1.433 | 0.486 | 0.354 | 0.927 | 0.817 | 0.237 |
| Carbonic Acid | 1.208 | Trace. | 0.652 | 1.267 | 2.251 | 6.934 | 0.419 | Trace. | 0.949 | 0.785 | 1.991 | 8.025 |
| Chlorin | 0.014 | 0.014 | 0.031 | 0.008 | 0.033 | 0.019 | 0.034 | 0.019 | 0.004 | 0.007 | 0.007 | 0.016 |
| Phosphoric Acid | 0.112 | 0.064 | 0.081 | 0.061 | 0.070 | 0.054 | 0.086 | 0.128 | 0.115 | 0.099 | 0.138 | 0.122 |
| Potash | 1.495 | 1.008 | 1.443 | 1.443 | 0.876 | 0.854 | 1.528 | 0.978 | 1.457 | 1.872 | 0.936 | 0.750 |
| Soda | 0.624 | 0.521 | 0.589 | 0.778 | 0.610 | 0.600 | 0.722 | 0.540 | 0.618 | 0.546 | 0.535 | 0.614 |
| Lime | 2.479 | 0.778 | 1.029 | 2.751 | 3.698 | 9.141 | 1.944 | 0.840 | 1.602 | 1.777 | 3.129 | 10.587 |
| Magnesia | 1.649 | 1.007 | 1.429 | 1.446 | 1.081 | 1.254 | 1.697 | 0.860 | 1.737 | 1.353 | 1.198 | 1.465 |
| Ferric Oxid | 4.075 | 3.575 | 4.185 | 4.225 | 4.025 | 3.680 | 4.320 | 3.385 | 4.960 | 4.170 | 3.795 | 3.600 |
| Aluminic Oxid | 7.387 | 4.484 | 5.587 | 6.733 | 4.853 | 5.190 | 7.410 | 4.264 | 7.281 | 6.492 | 4.499 | 3.756 |
| Manganic Oxid (br) | 0.200 | 0.120 | 0.140 | 0.190 | 0.075 | 0.065 | 0.245 | 0.180 | 0.290 | 0.095 | 0.085 | 0.190 |
| Moisture at 100° C | 3.296 | 1.765 | 2.004 | 2.214 | 2.020 | 1.642 | 2.990 | 1.526 | 2.853 | 2.721 | 2.109 | 1.850 |
| Ignition | 5.402 | 3.976 | 5.581 | 4.417 | 5.095 | 4.108 | 5.361 | 4.017 | 6.035 | 5.470 | 5.898 | 5.223 |
| Sum | 100.113 | 99.246 | 99.659 | 99.734 | 100.694 | 100.408 | 99.763 | 99.516 | 99.489 | 99.831 | 100.460 | 100.678 |
| Oxygen Equivalent to Chlorin. | 0.003 | 0.003 | 0.007 | 0.002 | 0.008 | 0.004 | 0.008 | 0.004 | 0.001 | 0.001 | 0.002 | 0.004 |
| Total | 100.110 | 99.243 | 99.652 | 99.732 | 100.686 | 100.399 | 99.755 | 99.512 | 99.488 | 99.830 | 100.458 | 100.674 |
| Nitrogen | 0.0937 | 0.0882 | 0.0882 | 0.0959 | 0.1295 | 0.1040 | 0.0938 | 0.1022 | 0.1015 | 0.1083 | 0.1191 | 0.0996 |
| Humus | 0.8150 | 0.9450 | 0.7360 | 0.6600 | 0.8080 | 0.5740 | 0.7120 | 0.9100 | 0.7400 | 0.8460 | 1.0800 | 0.5020 |
| Phosphoric Acid in Humus. | 0.0384 | 0.0205 | 0.0296 | 0.0288 | 0.0486 | 0.0384 | 0.0333 | 0.0345 | 0.0396 | 0.0294 | 0.0587 | 0.0834 |

## CONSIDERATION OF ANALYTICAL RESULTS.

§ 50. There is no division of soil into surface and subsoil, except in the case of samples E and F, where E is the soil and F the subsoil. The mechanical and chemical analyses both show that there are marked differences.

The subsoil disappears entirely a few feet east of this point, and is entirely wanting at the point where sample D, the next on the east, was taken. The subsoil contains less decomposable silicates, corresponding to the soluble silicic acid, a considerable quantity of carbonate of lime, and a different mechanical composition.

The surface soils vary more than would be expected, and not in the manner that a knowledge of their physical appearance and deportment under cultivation would lead one to anticipate. Soil A becomes heavily incrusted with alkalies, the incrustation reaching a thickness, at times, of one half inch, while soil E does not at any time show an incrustation and would not be considered as containing any alkali, except for the marked amount of sulfuric acid appearing in the analysis. The carbonic acid in both samples appears to be in combination with calcium to the extent of about 50 per cent. in the case of A, and probably a still greater extent in the case of E. This is the case if the water-soluble portion of the sample represents the salts present in the soil, and no changes are induced by the long treatment with water necessary to remove all the soluble salts. We notice that the sulfuric acid in the samples of A and E, taken in October, is higher than in the samples taken in May. This may be due to a transference of the sulfates from the subsoil to the soil, but taking the two series of samples, we see that only two samples indicate any loss of sulfates, *i. e.*, samples C and F; and as already suggested, the loss in F may account, in part, for the gain in E.

§ 51. The carbonic acid does not give us any strong indication that the season's cropping and cultivation has eliminated much if any alkali from the soil, while the total soda present tends to show that the apparent diminution in the carbonic acid present is to be explained otherwise than by attributing it to any variation of the quantity of alkali. Samples E and D are from contiguous sections. E shows no alkali on the surface, while D shows an abundance of it. If, for the sake of simplicity, we calculate the sulfuric acid as corresponding to sodic sulfate in the soil, we observe that in May it ranges from 0.87 to 1.63 per cent., whereas in October it ranges from 0.63 to 2.54 per cent., one sample only, C, showing a decrease from 0.90 to 0.63 per cent. In the case of the subsoil F, we have a decrease from 0.94 to 0.42 per cent, but in the surface soil E, corresponding to it, we have an increase from 0.92 to 1.45 per cent.

§ 52. This soil E is in excellent condition and would ordinarily be considered free from alkali, but if we calculate the amount of sodic sulfate corresponding to the sulfuric acid in an acre of such soil taken to the depth of one foot, we find in round numbers 16 tons in May, and 25 tons in October. In the subsoil, sample F, we find in May 16 tons and in October 7 tons. It appears that 9 tons of this salt, or its equivalent, has been transferred from the subsoil to the soil by surface evaporation and capillarity, but no incrustation was produced. In the case of sample A, we find a little larger increase in the surface layers, but there is at times a heavy incrustation covering almost the whole of this section. This was not the case at the time the sample was taken. We have a marked change in the other direction in sample C, as we find that about four tons per acre of this salt has passed below the depth to which our sample was taken. It is possible that this salt was washed out or flooded off of this section of the plot at the rate of four tons per acre during the season. I would like to believe this, but I see no reason why I should. The ground here is about one foot higher than at B or D, and the irrigation water flowed towards these points, but there was no increase in the alkali at either B or D. In the case of F there is a patent explanation, in the case of C there is not. The sulfuric acid determinations were done in duplicate in both cases, and agreed within four one hundredths of one per cent. The crop as previously shown did not remove a large amount of sulfuric acid, and I have no explanation for the disappearance of the alkali from this section, unless it was simply carried into the soil by the irrigation and was not brought back by the capillary movement of the water within the reach of our sample. The differences in the percentages of the potash are so small, and the samples not being identical, there is not even the same small object in trying to draw any inferences from them, that there is discussing the effect of the season's work on the "alkali," basing it upon the total amount of sulfuric acid present in the different samples.

One could scarcely expect one season's study and work to produce a change of sufficient magnitude to show a decided difference in the results of such anaylses, nor does the matter stand in a much more favorable relation at the end of three or four years. After three crops had been taken off of the plot, a sample from E showed the presence of 0.849 per cent. of potash, and before any crop had been taken off it showed 0.876 per cent. The plowing, cultivation, irrigation and cropping of three seasons gave us as their total effect this uncertain difference of 0.027 per cent. There were other samples taken, but these are the only two that coincide in the point at which they were taken. Others, however, show the same thing; sample B, for instance, at the beginning showed 1.003 per cent. of potash; after three crops had been taken, we obtained 0.999 per cent. This shows nothing, because the samples were not taken from points near enough together. The samples of the third season were not taken for the purposes of such a comparison, and merely chance to serve even in this measure. The fact that the nitrogen content in the October samples was higher than in the May samples, has but little if any dependence upon the beet crop, but was possibly very dependent upon the cultivation and irrigation. It is, we may say, a distinct crop, which increases with favorable conditions of season and soil; and our analyses simply show that there was more in the soil on October 20 than on May 13, regardless of what had been removed by the crop or dissolved out by water.

§ 53. The effect upon the organic matter in the soil did not seem to be very decided, but at the end of three seasons there was a gain, not so large, however, as I expected, the tops of two crops of beets and a heavy coating of manure having been added to one half, on alternate sections, of the plot.

§ 54. The analyses, as we ought to expect, do not show us the changes which have really taken place. This plot, for instance, has improved most wonderfully in its quality, and the analyses do not and cannot measure these improvements. It is not a question of composition, but one of conditions.

## SOME RESULTS DUE TO THE PRESENCE OF FELDSPAR.

§ 55. The consideration of the mineralogical constituents of the soil renders it evident that in our case we have to deal with the mineral feldspar, and indefinite decomposition products of this mineral, mixed with decaying organic matter. The agricultural analysis of the soil will yield results which will vary with the fineness of the feldspar particles the character of the decomposition products present, with slight variations in manipulation, and with other conditions which one cannot foresee. The minor variations, for instance in the percentages of potash found, as in case of sample A, 1.495 and 1.528, or in B, 1.003 and 0.978, may arise from such causes, and not depend in any way upon cropping or cultivation.

§ 56. As the solubility of feldspar in dilute acids is a well recognized property of this whole class of minerals, the results of the mineralogical study of these samples was somewhat disconcerting, not in regard to the value of such analyses in general, but of my analyses in particular. The abundance of this mineral present, the abundance of potash soluble in dilute acid, and the impossibility of washing out all the lime, soluble in dilute hydrochloric acid in any reasonable time, led me to experiment with orthoclase, powered so fine that the whole mass would pass through a sieve with one millimeter mesh, because this is the conventional size of the particles of fine earth. Thirty-three per cent. of this was less than one quarter of a millimeter in diameter. The mechanical analyses of the soils show that 60 per cent. of the soil particles are smaller than one fourth of a millimeter in diameter. This feldspar used had been washed out of the soil and was treated just as the soil was, and the results were as follows: Potash dissolved out of the feldspar by digesting with hydrochloric acid, sp. gr. 1.115, for five days, was 0.845 per cent.; soda, 0.816 per cent.; silicic acid set free, 4.31 per cent. This simple experiment is so decisive of the fact that five days digestion with dilute hydrochloric acid, sp. gr. 1.115, will extract potash from finely divided orthoclase in considerable quantities, that further questions arise as to whether plants can use the potash present in this form, or is our analysis of such a soil wholly misleading? The following questions are also suggested, viz: To what extent does water alone act on this mineral, for that water extracts potash from it is already an established fact, and how much does carbonic acid increase its solvent action?

### ACTION OF WATER AND CARBONIC ACID ON FELDSPAR.

§ 57. The perfectly fresh, finely pulverized feldspar was suspended in water, 10 grams in 300 c. c., and allowed to stand five days with frequent shaking. One hundred c. c. of this solution was filtered off, evaporated to dryness, and the residue weighed. Another portion of feldspar was treated in the same manner, except that the water was saturated with carbonic oxid.

§ 58. A like quantity of water was placed beside these and carried through as a control.

§ 59. The water dissolved from the feldspar 0.0081 gram, after deducting the amount contained in the distilled water.

§ 60. The water charged with carbonic oxid dissolved 0.0723 gram. The residue obtained in this case gave a heavy precipitate for potash with platinic chlorid, as did the water solution of the feldspar. The residue from the distilled water did not react for potash.

### EXPERIMENTS WITH OATS.

§ 61. This question was carried still further, and we endeavored to determine whether the feldspar could furnish potash to plants. For this purpose the perfectly fresh mineral was used, pulverized as already described in imitation of the soil, *i. e.*, the particles varied from one millimeter in diameter to an impalpable powder. This was mixed with pure quartz sand. Bone ash was used to supply lime and phosphoric acid. The sample used contained no potash. Nitrate of lime furnished the nitrogen. Chlorin was furnished by a minute quantity of calcic chloride. Distilled water was used throughout the experiment.

The plants grew healthily in this mixture until the floors of the building were oiled and the room in which the plants were growing was shut up and became too warm; these two things together gave them a decided set back, and later a thrips, *Thrips striata*, according to Prof. Gillette, attacked the plants and did them much damage. Some of the plants, however, seeded. They were harvested, though in bad condition and very uneven in the degree of their development. The root system was well developed, the sand being filled with the roots. The weight of the tops as harvested was 198.5 grams; that of the roots as washed out was 40 grams. The tops and roots were incenerated together and yielded 5.795 per cent. of soluble and 9.803 per cent. of insoluble ash, a total of 15.598 per cent.

§ 62. Examination of the feldspar used showed the presence of 11.993 per cent. of potash, and 2.988 per cent. of soda. Phosphoric and sulfuric acids were present in very small quantities, the former equalled 0.041 per cent. and the latter 0.003 per cent. of the feldspar.

§ 63. The nitrogen in the oat hay, roots included, was 3.2543 per cent.

The ash gave the following analysis:

TABLE VI.—ANALYSIS OF OAT ASH GROWN WITH FELDSPAR.

| | Per Cent |
|---|---|
| Carbon | 0.172 |
| Sand | 8.135 |
| Silicic Acid | 15.737 |
| Sulfuric Acid | 4.411 |
| Phosphoric Acid | 3.982 |
| Carbonic Acid | 15.356 |
| Chlorin | 2.732 |
| Potassic Oxid | 15.959 |
| Sodic Oxid | 4.622 |
| Calcic Oxid | 21.709 |
| Magnesic Oxid | 3.906 |
| Ferric Oxid | 0.696 |
| Aluminic Oxid | 0.314 |
| Manganic Oxid | 0.163 |
| Ignition | 2.611 |
| Sum | 100.505 |
| Oxygen Equivalent to Chlorin | 0.615 |
| Total | 99 890 |

### RESULTS SHOWN BY EXPERIMENT WITH FELDSPAR.

§ 64. This ash is very anomalous in its composition as well as in the quantity present in the plants. The plants were not evenly mature at the time of gathering and were in bad condition. The question we endeavored to investigate, however, is perfectly answered by the results, *i. e.*, the oat plant can use the finely divided feldspar as a source from which to obtain potash; for in this experiment, made under very adverse conditions, we find that the oat plants took from the feldspar 1.4417 grams of potash. The potash added in the seed has been deducted. The silicic acid appropriated by the plant indicates the decomposition of the silicate. The partially decomposed, finely comminuted feldspar is actually a part of the soil. Its deportment toward water, especially when charged with carbonic oxid, is also strongly suggestive of this conclusion.

§ 65. This fact is of very general importance, as it applies to so large a portion of our soils; it also facilitates the interpretation of our analytical data, and enhances their value a little. The mass analyses show that our soils contain from 2.24 to 2.50 per cent. of potash—the latter seems to be the rule, about 2.50 per cent. The agricultural analysis of samples from all parts of the State show a range from 0.10 to 1.50 per cent. In fifty-eight analyses of samples from different counties of the State, only five fall so low as 0.15, and very few of the rest so low as 0.25 per cent. It is evident that, so far as the results of analyses are reliable, the soil with which we have been experimenting is richer in this constituent than the average soil. This is, I believe, true of all of alkali land.

### ANALYSIS OF THE ACID SOLUBLE AND INSOLUBLE PORTION OF SOIL A.

§ 66. The mineralogical composition of our soil, *i. e.*, quartz and feldspar, and the decomposition products of the latter, together with the results of our experiments with feldspar, suggest the combination of the mass analysis and agricultural analysis to give us some idea of the relation of the agricultural analysis to the actual composition of the soil. We, therefore, in order to exhibit as fully as we can the chemical composition of this soil, give the agricultural analysis of soil A, together with the analysis of the residue designated as insoluble in the agricultural analysis.

TABLE VII.—ANALYSES OF THE ACID SOLUBLE AND INSOLUBLE PORTION OF SOIL A.

| | *Soluble in HCl., sp. gr. 1.115, 5 days digestion. Per cent.* | *Insoluble in HCl., sp. gr. 1.115, 5 days digestion. Per cent.* |
|---|---|---|
| Silicic Acid | 17.875 | 46.870 |
| Sulfuric Acid | 0.827 | None |
| Carbonic Acid | 1.208 | ...... |
| Chlorin | 0.014 | ...... |
| Phosphoric Acid | 0.112 | None |
| Potash | 1.495 | 0.800 |
| Soda | 0.624 | 0.560 |
| Lime | 2.479 | 0.310 |
| Magnesia | 1.649 | 0.170 |
| Ferric Oxid | 4.075 | 0.400 |
| Aluminic Oxid | 7.387 | 4.330 |
| Manganic Oxid | 0.200 | Trace |
| Moisture at 100° C | 3.296 | ...... |
| Ignition | 5.402 | ...... |
| | 46.640 | 53.440 |
| Total | | 100.080 |

### DISCUSSION OF ANALYSIS.

§ 67. This analysis shows that 65 per cent. of the potash, 63 per cent. of the alumina, 90 per cent. of the oxid of iron, 27.6 per cent of the silicic acid, a very high percentage of the lime and magnesia, and the whole of the sulfuric and phosphoric acids, were removed or, as in the case of the silicic acid, rendered soluble in sodic carbonate. If the silicic acid rendered soluble by this treatment be taken as the measure, then the action of the hydrochloric acid on the soil was between six and seven times as great as it was on pure feldspar, and probably not more than one sixth of the silicic acid could come from the decomposition of this mineral. The potash dissolved out of the soil is about 75 per cent. greater than was taken into solution from the pure, fresh mineral. The relative amount of soda dissolved out of the feldspar was high compared with the amount of potash dissolved, but low when compared with the percentage of soda dissolved out of the soil. A glance at the analysis shows that, taken roughly, 50 per cent. of the soda in the soil was dissolved out, but only about 25 per cent. of it went into solution in the case of the feldspar. The relatively large amount of soda dissolved out of the feldspar by digestion with the dilute hydrochloric acid, is probably due to the fact that the feldspar used was not wholly composed of the potash feldspar, orthoclase, but may have contained an admixture of oligoclase, another feldspar, rich in soda and more readily attacked by acids. When we take up the portion of the soil soluble in water we shall see that some, as much perhaps as one third, of the soda is present in a form readily soluble in this menstruum, and in this case belongs to the "alkalis" present.

### THE WATER-SOLUBLE IN THE SOIL.

§ 68. When these soils are treated with fresh portions of water, so long as they yield either chlorin or sulfuric acid to the water and the amount taken into solution is determined, we find it ranging from 0.389 per cent. to 2.550 per cent. Soil A yielded the highest amount to water, 2.55 per cent., taking the sample to a depth of ten inches, and as high as 3.93 per cent. taking the first two inches of the soil.

§ 69. In stating the analyses of the portions of different samples soluble in water, I have combined the acids and bases and give the salts alongside of the direct analytical results. The order followed in combining them will be apparent to anyone upon an inspection of an analysis. I have adopted this order and have been as uniform as possible throughout. This order is convenient and probably represents the salts present in the soil as nearly as any other which might have been adopted, but it is certainly not always correct.

§ 70. The water-soluble has been determined in one set of general samples, but has been analyzed in only one case, that of sample B, taken in 1897. The analysis is not wholly satisfactory, showing too large an excess of sodic oxid, even after using all of the silicic acid present. A large quantity of organic matter in an analysis is sometimes accompanied by an excess of soda. This analysis was made on a smaller amount of material than the analyist was accustomed to, and other conditions did not contribute either to his comfort or to the accuracy of his work. The water-soluble amounted in this instance to 0.878 per cent. of the soil.

TABLE VIII.—ANALYSIS OF THE WATER-SOLUBLE IN SAMPLE B, 1897.

| | *Per cent.* |
|---|---|
| Silicic Acid | 1.516 |
| Sulfuric Acid | 50.451 |
| Carbonic Acid | 0.140 |
| Chlorin | 1.529 |
| Sodic Oxid | 14.423 |
| Potassic Oxid | 2.517 |
| Calcic Oxid | 15.091 |
| Magnesic Oxid | 7.608 |
| Aluminic and Ferric Oxids | 0.152 |
| Manganic Oxid (br) | not det. |
| Ignition | 6.885 |
| Sum | 100.312 |
| Oxygen Equivalent to Chlorin | 0.344 |
| Total | 99.968 |

| *Combined.* | *Per cent.* |
|---|---|
| Calcic Sulfate | 36.633 |
| Magnesic Sulfate | 22.824 |
| Potassic Sulfate | 4.659 |
| Sodic Sulfate | 20.513 |
| Sodic Chlorid | 2.523 |
| Sodic Carbonate | 0.337 |
| Sodic Silicate | 3.078 |
| Aluminic and Ferric Oxids | 0.152 |
| Manganic Oxid | not det. |
| Ignition | 6.885 |
| Sum | 97.604 |
| Excess of Soda | 2.400 |
| Total | 100.004 |

§ 71. Analysis shows that the whole of the sulfuric acid in these soils is soluble in water and in hydrochloric acid. The soil analysis of B, sample taken May 13, was made on the same sample that was extracted with water and the analysis of which extract is given above. The difference when the sulfuric acid is calculated into percentage of the soil is far within the limit of the analytical errors, being only 0.045 per cent. In regard to the order in which the acids and bases have been combined, it appears that there is but little choice. The water-soluble consists essentially of sulfates. The above residue was obtained by washing the soil so long as the water with which it was digested in the cold for twenty-four hours showed any trace of sulfuric acid. The water used in the particular case given, sample B, was not measured, but it was in all of the cases to be given and ranged from 18 to 45.5 litres per 1,000 grams of the soil.

## THE WATER-SOLUBLE PORTION OF THE SOIL DIFFERENT FROM THE INCRUSTATION.

§ 72. It may be well to anticipate a later discussion to the extent of stating that the water-soluble in the soil is not the same, as the "alkali" that effloresces from the soil. The salts are of the same kind, sulfates, but while the predominant soluble salt in the soil is calcic sulfate, that in the alkali which effloresces from this ground is sodic sulfate, with magnesic sulfate second in quantity, while the calcic sulfates is but little greater than the sodic chlorid.

§ 73. The analysis is not unsupported in showing a large amount of calcic sulfate to be present. I caused several boxes of the soil to be gathered and planted with beet seed. These boxes were covered with glass and left standing for some days. When they were examined again there was an abundant crop of fine acicular crystals of gypsum uniformly distributed over the surface. Inspection of the soil as it was turned up by the plow also showed this substance to be present. Its abundance suggested the possibility of this soil having sometime received a heavy dressing of gypsum, in the hope of correcting the evil of the alkali, but I could not learn that such had been the case, and the presence of the gypsum in its present quantity seems to be due to accumulation of this salt from the evaporation of the ground water.

### WATER-SOLUBLE PORTION OF THE SOIL DIFFERENT FROM SALTS IN GROUND WATER.

§ 74. The salts held in solution by the ground water agree more nearly with the water soluble in the soil than those which effloresce and are considered as alkali, but even the ground waters are not solutions of the water soluble portion in the soil. They differ in two essentials, in the amount of silicic acid and also in that of potash, which they contain. The water-soluble portion of the soils being richer in these constituents, sometimes containing ten times as much of one or the other of these. The water-soluble in the soil, on the other hand, is not at all uniform in its relative content of sodic sulfate, and is oftener poor in this salt than even mediumly rich. In only two cases out of the eight following analyses does it constitute any considerable fraction of the water-soluble salts, and in these cases its presence in such large quantity, 17.7 and 27.2 per cent. of the soluble salts, is probably due to its concentration at the surface and its subsequent washing back into the soil, as the samples represented the first two inches of the soil from sections where efflorescences are always formed under favorable conditions. The fact that the water-soluble salts are richer in potash than the soil water is explicable by the facts which have been demonstrated, by the action of water on the feldspar and the property of certain compounds in the soil of exchanging lime for potash brought into contact with them through the agency of solutions, the ground water being in this manner deprived of its potash, receiving lime in exchange. The analyses of the parts of the soil classified according to the size of their grains showed an increasing percentage of potash as the grains of the respective parts became finer, until it reached its maximum in the dust and clay. The continued treatment with pure water, used in small portions at a time, yet relatively large compared with that acting upon the same amount of soil in the field, may act more energetically upon the feldspar than the soil waters do, but in considering this the presence of carbonic acid in the soil is not to be neglected, as it strongly tends to increase the solvent action of water upon this mineral.

§ 75. The analyses of the water-soluble portion of these soils show, as a rule, very much more silicic acid than is present in the residues from the ground waters. This fact, together with the higher percentage of potash which the water-soluble portions uniformly contain, suggest that the reaction itself is either primarily different or that there is a subsequent reaction between the ground water solution and the soil. The known ability of soils to remove potash from solutions seems to make it probable that such secondary reaction takes place. The more exact nature of this reaction is not known. I believe, however, that such a reaction would account very largely, if not wholly, for the accumulation of the potash in the very fine portions of the soil, among which these newly formed and highly reactive compounds are included.

### THE WATER-SOLUBLE PORTION OF THE SOIL.

§ 76. The following tables exhibit the composition of the water-soluble portions of the first and second two inches of the soil. They give us an idea of the differences which exist in the salts of the different layers of the soil, but no correct idea of the distribution of the alkali, for the samples were taken on different dates.

That which has already been said in regard to the order in which the acids and bases, oxids, have been combined probably needs to be emphasized. The order adopted seems to be the most convenient one for the majority of cases, and approximates the facts in these cases, but is not always correct. Phosphoric acid, when found in these residues, has been combined with magnesia. While this may be correct, it is more probable that it was in combination with lime. Its quantity, however, is so small that no great violence is done to our knowledge or to the facts.

## TABLE IX.—WATER-SOLUBLE, SOIL A, FIRST TWO INCHES.

| | *Per cent.* |
|---|---|
| Silicic Acid | 0.574 |
| Sulfuric Acid | 49.411 |
| Phosphoric Acid | None |
| Carbonic Acid | 0.721 |
| Chlorin | 5.557 |
| Potassic Oxid | 1.223 |
| Sodic Oxid | 14.301 |
| Calcic Oxid | 16.189 |
| Magnesic Oxid | 7.635 |
| Aluminic and Ferric Oxids | Trace |
| Manganic Oxid | 0.297 |
| Ignition | 5.058 |
| Sum | 100.966 |
| Oxygen Equivalent to Chlorin | 1.252 |
| Total | 99.714 |

| *Combined.* | *Per cent.* |
|---|---|
| Calcic Sulfate | 39.289 |
| Magnesic Sulfate | 22.924 |
| Potassic Sulfate | 2.263 |
| Sodic Sulfate | 17.728 |
| Sodic Chlorid | 9.167 |
| Sodic Carbonate | 1.737 |
| Sodic Silicate | 1.165 |
| Aluminic and Ferric Oxids | Trace |
| Manganic Oxid | 0.297 |
| Ignition | 5.058 |
| Sum | 99.628 |
| Excess of Sodic Oxid | 0.081 |
| Total | 99.709 |

The percentage of water-soluble equalled 3.93.

## TABLE X.—WATER-SOLUBLE, SOIL A, SECOND TWO INCHES.

| | *Per cent.* |
|---|---|
| Silicic Acid | 1.999 |
| Sulfuric Acid | 51.740 |
| Phosphoric Acid | 0.129 |
| Carbonic Acid | 3.092 |
| Chlorin | 0.939 |
| Potassic Oxid | 1.490 |
| Sodic Oxid | 4.429 |
| Calcic Oxid | 26.617 |
| Magnesic Oxid | 7.591 |
| Aluminic and Ferric Oxids | 0.161 |
| Manganic Oxid | 0.209 |
| Ignition | 2.173 |
| Sum | 100.569 |
| Oxygen Equivalent to Chlorin | 0.212 |
| Total | 100.357 |

| *Combined.* | *Per cent.* |
|---|---|
| Calcic Sulfate | 64.594 |
| Magnesic Sulfate | 20.642 |
| Magnesic Phosphate | 0.229 |
| Magnesic Carbonate | 1.285 |
| Potassic Carbonate | 2.185 |
| Sodic Carbonate | 4.157 |
| Sodic Chlorid | 1.549 |
| Sodic Silicate | 2.312 |
| Aluminic and Ferric Oxids | 0.161 |
| Manganic Oxid | 0.209 |
| Ignition | 2.173 |
| Sum | 99.496 |
| Excess of Silicic Acid | 0.861 |
| Total | 100.357 |

The percentage of water-soluble equalled 2.55.

## TABLE XI.—WATER-SOLUBLE, SOIL B, FIRST TWO INCHES.

| | *Per cent.* |
|---|---|
| Silicic Acid | 1.348 |
| Sulfuric Acid | 47.649 |
| Phosphoric Acid | None |
| Carbonic Acid | 1.311 |
| Chlorin | 4.008 |
| Potassic Oxid | 2.048 |
| Sodic Oxid | 18.632 |
| Calcic Oxid | 13.900 |
| Magnesic Oxid | 5.365 |
| Aluminic and Ferric Oxids | 0.113 |
| Manganic Oxid | 0.266 |
| Ignition | 6.281 |
| Sum | 100.921 |
| Oxygen Equivalent to Chlorin | 0.903 |
| Total | 100.018 |

| *Combined.* | *Per cent.* |
|---|---|
| Calcic Sulfate | 33.733 |
| Magnesic Sulfate | 16.108 |
| Potassic Sulfate | 3.789 |
| Sodic Sulfate | 27.229 |
| Sodic Chlorid | 6.612 |
| Sodic Carbonate | 3.158 |
| Sodic Silicate | 2.714 |
| Aluminic and Ferric Oxids | 0.113 |
| Manganic Oxid | 0.266 |
| Ignition | 6.281 |
| Sum | 100.003 |
| Excess of Silicic Acid | 0.012 |
| Total | 100.015 |

The percentage of the water-soluble equalled 0.75.

### TABLE XII.—WATER-SOLUBLE, SOIL B, SECOND TWO INCHES.

| | Per cent. |
|---|---|
| Silicic Acid | 6.768 |
| Sulfuric Acid | 40.378 |
| Phosphoric Acid | 0.407 |
| Carbonic Acid | 4.738 |
| Chlorin | 2.821 |
| Potassic Oxid | 2 042 |
| Sodic Oxid | 9.826 |
| Calcic Oxid | 19.165 |
| Magnesic Oxid | 6.954 |
| Aluminic and Ferric Oxids | 0.390 |
| Manganic Oxid | 0.760 |
| Ignition | [6.387] |
| Sum | 100.636 |
| Oxygen Equivalent to Chlorin. | 0.636 |
| Total | 100.000 |

| Combined. | Per cent. |
|---|---|
| Calcic Sulfate | 46.510 |
| Magnesic Sulfate | 16.939 |
| Magnesic Phosphate | 0.751 |
| Magnesic Chlorid | 2.296 |
| Potassic Sulfate | 3.778 |
| Sodic Chlorid | 1.825 |
| Sodic Carbonate | 11.414 |
| Sodic Silicate | 4.295 |
| Aluminic and Ferric Oxids | 0.390 |
| Manganic Oxid | 0.760 |
| Ignition | [6.387] |
| Sum | 95.345 |
| Excess of Silicic Acid | 4.654 |
| Total | 99.999 |

**The percentage of water-soluble equalled 0.389.**

### TABLE XIII.—WATER-SOLUBLE, SOIL C, FIRST TWO INCHES.

| | Per cent. |
|---|---|
| Silicic Acid | 1.084 |
| Sulfuric Acid | 48.826 |
| Phosphoric Acid | None |
| Carbonic Acid | 0.385 |
| Chlorin | 4.321 |
| Potassic Oxid | 1.338 |
| Sodic Oxid | 10.190 |
| Calcic Oxid | 17.826 |
| Magnesic Oxid | 8.080 |
| Aluminic and Ferric Oxids | ——— |
| Manganic Oxid | 0.342 |
| Ignition | 8.281 |
| Sum | 100.673 |
| Oxygen Equivalent to Chlorin. | 0.973 |
| Total | 99.700 |

| Combined. | Per cent. |
|---|---|
| Calcic Sulfate | 43.260 |
| Magnesic Sulfate | 24.260 |
| Potassic Sulfate | 2.475 |
| Sodic Sulfate | 10.789 |
| Sodic Chlorid | 7.128 |
| Sodic Carbonate | 0.928 |
| Sodic Silicate | 2.202 |
| Aluminic and Ferric Oxids | – |
| Manganic Oxid | 0.342 |
| Ignition | 8.281 |
| Sum | 99.665 |
| Excess of Sodic Oxid | 0.031 |
| Total | 99.696 |

**The percentage of water-soluble equalled 2.0544.**

### TABLE XIV.—WATER-SOLUBLE, SOIL C, SECOND TWO INCHES.

| | Per cent. |
|---|---|
| Silicic Acid | 9.095 |
| Sulfuric Acid | 34.832 |
| Phosphoric Acid | 0.522 |
| Carbonic Acid | 5.558 |
| Chlorin | 2.663 |
| Potassic Oxid | 3.252 |
| Sodic Oxid | 8.778 |
| Calcic Oxid | 20.981 |
| Magnesic Oxid | 7.131 |
| Aluminic and Ferric Oxids | 0.878 |
| Manganic Oxid | 0.245 |
| Ignition | 6.996 |
| Sum | 100.951 |
| Oxygen Equivalent to Chlorin. | 0.600 |
| Total | 100.351 |

| Combined. | Per cent. |
|---|---|
| Calcic Sulfate | 50.917 |
| Magnesic Sulfate | 3.197 |
| Potassic Sulfate | 6.016 |
| Magnesic Phosphate | 0.963 |
| Magnesic Chlorid | 3.565 |
| Magnesic Carbonate | 8.646 |
| Sodic Carbonate | 2.490 |
| Sodic Silicate | 14.418 |
| Aluminic and Ferric Oxids | 0.898 |
| Manganic Oxid | 0.245 |
| Ignition | 6.996 |
| Sum | 98.351 |
| Excess of Silicic Acid | 1.998 |
| Total | 100.349 |

**The percentage of water-soluble equalled 0.813.**

### TABLE XV.—WATER-SOLUBLE, SOIL D, FIRST TWO INCHES.

| | *Per cent.* |
|---|---|
| Silicic Acid | 2.261 |
| Sulfuric Acid | 48.354 |
| Phosphoric Acid | ——— |
| Carbonic Acid | 0.768 |
| Chlorin | 2.670 |
| Potassic Oxid | 3.792 |
| Sodic Oxid | 5.604 |
| Calcic Oxid | 22.084 |
| Magnesic Oxid | 5.486 |
| Aluminic and Ferric Oxids | 0.011 |
| Manganic Oxid | 0.662 |
| Ignition | 8.789 |
| Sum | 100.477 |
| Oxygen Equivalent to Chlorin | 0.602 |
| Total | 99.875 |

| *Combined.* | *Per cent.* |
|---|---|
| Calcic Sulfate | 53.593 |
| Magnesic Sulfate | 16.473 |
| Potassic Sulfate | 7.015 |
| Sodic Sulfate | 4.682 |
| Sodic Chlorid | 4.405 |
| Sodic Carbonate | 1.841 |
| Sodic Silicate | 0.282 |
| Aluminic and Ferric Oxids | 0.011 |
| Manganic Oxid | 0.662 |
| Ignition | 8.789 |
| Sum | 97.753 |
| Excess of Silicic Acid | 2.122 |
| Total | 99.875 |

The percentage of water-soluble equalled 0.800.

### TABLE XVI.—WATER-SOLUBLE, SOIL D, SECOND TWO INCHES.

| | *Per cent.* |
|---|---|
| Silicic Acid | 3.354 |
| Sulfuric Acid | 44.392 |
| Phosphoric Acid | Trace |
| Carbonic Acid | 5.738 |
| Chlorin | 0.632 |
| Potassic Oxid | 1.310 |
| Sodic Oxid | 5.594 |
| Calcic Oxid | 27.656 |
| Magnesic Oxid | 5.895 |
| Aluminic and Ferric Oxids | 0.443 |
| Manganic Oxid | 0.227 |
| Ignition | 4.919 |
| Sum | 100.160 |
| Oxygen Equivalent to Chlorin | 0.142 |
| Total | 100.018 |

| *Combined.* | *Per cent.* |
|---|---|
| Calcic Sulfate | 67.116 |
| Magnesic Sulfate | 7.397 |
| Magnesic Carbonate | 7.202 |
| Potassic Carbonate | 1.922 |
| Sodic Chlorid | 1.042 |
| Sodic Carbonate | 3.265 |
| Sodic Silicate | 6.164 |
| Aluminic and Ferric Oxids | 0.443 |
| Manganic Oxid | 0.227 |
| Ignition | 4.919 |
| Sum | 99.697 |
| Excess of Silicic Acid | 0.321 |
| Total | 100.018 |

The percentage of water-soluble equalled 0.864.

§ 77. The quantity of water used in extracting the soils ranged from 18 to 45.5 litres, and the time of extracting from 14 to 68 days. It was thought that the long time and large quantities of water used might have made some differences in the results which a quick extraction would make evident, but two experiments made on quantities of 10 and 150 grams each failed to show anything of sufficient interest to lead us to prosecute the work. The silicic acid, sulfuric acid, lime and magnesia extracted from 10 grams in from 30 to 45 minutes differed but a few hundredths of a per cent., when calculated on the soil used, from the figures obtained in the more carefully prepared extract. In the experiment with 150 grams the alkalies and magnesia with the silicic acid went into solution more readily than the last portions of lime and sulfuric acid. This is entirely in accordance with the properties of these sulfates, but tends to show that the silicic acid is present as easily soluble silicates, probably as an alkaline silicate.

### THE DISTRIBUTION OF THE SALTS IN THE FIRST AND SECOND TWO INCHES OF THE SOIL.

§ 78. I regret exceedingly that these sets of samples were not taken on the same date, but the record shows them to have been taken nearly a year apart. The set representing the first two inches having been taken in June, 1899, and that representing the second two inches in May, 1900. The two series are not comparable, except in a very general way, but the members of the series are perfectly so among themselves. The larger features of their differences are probably thoroughly representative of the facts, and show that the first two inches of the soil contains a somewhat higher percentage of soluble salts than the second two inches; that the sodic and magnesic sulfates constitute a materially higher percentage of these salts than they do in the second two inches; that the first two yielded less silicic acid than the second two inches; that the potassic oxid soluble in water is very irregular, but is present in both series in significant quantities; that there is no soluble phosphoric acid in the series representing the first two inches, and is present throughout that representing the second two inches. I was at first inclined to think that this was an error, but it is not. The plots from which these samples were taken had been cultivated, but had not received any manure.

§ 79. The uniformity of the presence of phosphoric acid as well as the significant quantity in which it is present is a matter of some surprise. Phosphoric acid is sometimes present in drainage waters in appreciable quantities, but usually only in traces. I have repeatedly tested the residues obtained by evaporating the ground waters of this plot for phosphoric acid, but I have not been able to prove the presence of a trace of it.

In regard to the silicic acid, a trifling amount of it might have been derived from the glass by solution, aided by the repeated shaking of the mass in the bottles, but the solutions made quickly, using freshly distilled water, gave the same results.

### THE ALKALI.

§ 80. The efflorescence which forms on the surface of the soil is popularly called alkali, and is of common occurrence in many places in all parts of the State. It is not my intention to go into this subject at present, except as it pertains to this particular soil.

§ 81. There are small areas almost everywhere, especially in irrigated sections, which at times are white with a crop of these salts. They are not sightly from the agriculturists' standpoint, but are much less injurious in themselves than the conditions which admit of their formation. We have seen that among the salts present in the soil are sodic, magnesic and calcic sulfates, and sodic chlorid. This is not the order, according to the respective quantities in which they occur in the soil, but in the incrustation formed on the top of the soil. There is an order, seemingly, in which the salts come to the surface or are brought there by capillary action, the sodic and magnesic sulfates forming some 80 per cent. of the total salts brought to the surface and deposited from the solutions in this soil. The character of these deposits, these alkalies, will vary in different localities. This variation undoubtedly depends upon the nature of the solutions in the soil, *i. e.*, the salts present in the ground water, rather than upon the nature of the water extract which we may be able to make of the soil. The salts present in the ground waters are intermediate in the order of their relative quantities between the water-soluble in the soil and the alkali incrustation, but are of the same kind. The analyses already given of the water-soluble salts, and those given in the following tables, represent the extremes for our soil.

TABLE XVII.—ANALYSIS OF ALKALI FROM SOIL A, JUNE 23, 1897.

| | *Per cent.* |
|---|---|
| Silicic Acid | 0.282 |
| Sulfuric Acid | 53.637 |
| Carbonic Acid | 0.513 |
| Chlorin | 2.103 |
| Potassic Oxid | 0.520 |
| Sodic Oxid | 28.259 |
| Calcic Oxid | 3.097 |
| Magnesic Oxid | 9.136 |
| Aluminic and Ferric Oxids | 0.090 |
| Manganic Oxid | 0.117 |
| Ignition | 3.112 |
| Sum | 100.596 |
| Oxygen Equivalent to Chlorin | 0.474 |
| Total | 100.122 |

| *Combined.* | *Per cent.* |
|---|---|
| Calcic Sulfate | 7.518 |
| Magnesic Sulfate | 27.408 |
| Potassic Sulfate | 0.963 |
| Sodic Sulfate | 53.682 |
| Sodic Chlorid | 3.470 |
| Sodic Carbonate | 1.237 |
| Sodic Silicate | 0.572 |
| Aluminic and Ferric Oxids | 0.090 |
| Manganic Oxid | 0.117 |
| Ignition | 3.112 |
| Sum | 98.168 |
| Excess of Sodic Oxid | 1.954 |
| Total | 100.123 |

TABLE XVIII.—ANALYSIS OF ALKALI FROM SOIL A, JULY 5, 1897.

| | *Per cent.* |
|---|---|
| Silicic Acid | 0.129 |
| Sulfuric Acid | 52.127 |
| Carbonic Acid | 0.488 |
| Chlorin | 5.574 |
| Potassic Oxid | 0.315 |
| Sodic Oxid | 29.785 |
| Calcic Oxid | 1.369 |
| Magnesic Oxid | 9.684 |
| Aluminic and Ferric Oxids | 0.111 |
| Manganic Oxid | 0.101 |
| Ignition | 1.571 |
| Sum | 101.254 |
| Oxygen Equivalent to Chlorin | 1.256 |
| Total | 99.998 |

| *Combined.* | *Per cent.* |
|---|---|
| Calcic Sulfate | 3.323 |
| Magnesic Sulfate | 29.059 |
| Potassic Sulfate | 0.580 |
| Sodic Sulfate | 54.217 |
| Sodic Chlorid | 9.198 |
| Sodic Carbonate | 1.177 |
| Sodic Silicate | 0.262 |
| Aluminic and Ferric Oxids | 0.111 |
| Manganic Oxid | 0.101 |
| Ignition | 1.571 |
| Sum | 99.601 |
| Excess of Sodic Oxid | 0.396 |
| Total | 99.997 |

These analyses are sufficient to show how very different the percentages of the various salts are in the alkali, and in that portion of the soil which is soluble in water. The latter contains a relatively small amount of sodic sulfate, the former a large amount. The sodic sulfate, together with the magnesic sulfate, is concentrated in the alkali.

### FORMATION OF ALKALI INCRUSTATIONS EXPLAINED.

§ 82. The formation of these incrustations effects a rough separation of the markedly efflorescent salts, sodic and magnesic sulfates, from the permanent calcic sulfate. Ordinary salt, sodic chlorid, which is present, is also concentrated in the alkali, but not nearly to a like extent, as those already named. The highest figure obtained for the sodic sulfate in any sample of the water-soluble is in the first two inches of soil designated as B, in which it amounts to 27 per cent. In the alkalies it is practically 54 per cent., or twice as much. The highest percentage of magnesic sulfate in the water-soluble is 24 per cent., found in the first two inches of the soil C, while the average for the two samples of alkali is 28 per cent. The decrease of the calcic sulfate from the amount present in the water-soluble to that present in the alkali, is more marked than the increase in the sodic sulfate in the alkali given above. The minimum of the calcic salt found in the water-soluble is 34 per cent., the maximum 67 per cent., while the amount in these alkalies are 7.5 and 3.3 per cent., respectively. These relations show us the deportment of these salts when present in the soil solutions, whose surfaces are brought up and exposed to the evaporating influences of the atmosphere and sun. It is quite a different matter when the free surface of the water in lakes and ponds is presented to the same. In this case there is simply an evaporation to dryness, and the residue represents the salts held in solution by the waters, whereas, in the efflorescing alkalies we have the chemical and physical properties of these salts playing an important, if not the most important part. The sodic sulfate is predominant in the alkali, not because there is more of it in solution in the soil, but because it is separated more readily at the surface of the solution than the calcic sulfate. Magnesic sulfate also passes out of the solution more readily than the calcic sulfate, not because there is more of it in the solution, but because its chemical properties are different and its department toward the dissolving water and the soil particles is different. This subject will be discussed more fully and facts given, when we consider the soil waters. I wish, however, to emphasize the fact that the efflorescent alkalies are quite different from the residues left by evaporating bodies of water; such residues seem to be intermediate between those obtained by evaporating ground waters to dryness and the salt brought to the surface by capillarity and separated as efflorescences on the ground.

### ALKALINITY OF THIS SOIL.

§ 83. Several attempts were made to estimate the alkalinity of the soil, but without satisfactory results. It was simply determined that they all reacted with cochineal and a properly prepared litmus solution, showing an alkaline reaction. This reaction was more decided when the moistened soil was placed on litmus paper and allowed to remain there for a few minutes. While the samples were all alkaline, none of them were strongly enough so to permit of its determination by a one hundredth normal acid solution. I was not at all satisfied as to the cause of the alkaline reaction, for the samples of soil which had been washed free from the sulfates still showed the reaction when placed on litmus paper.

### FREE AMMONIA IN THE SOIL.

§ 84. Though aware of the unsatisfactory results obtained in endeavors to make this determination, I thought that the peculiar character of our soil and the very frequent occurrence of similar soils in Colorado, would justify me in making the attempt.

§ 85. The samples were taken in their fresh condition, magnesic oxid added, and after standing a short time, an hour or so, were subjected to distillation. Ammonia-free-water was used throughout this experiment. The disillate at first was rich in ammonia, and while it became poorer and poorer, it continued to give a decided reaction with Nessler's reagent for ten days, when the experiment was stopped. It the case of sample No. 3, the whole of the ammonia was given off in four days. Three samples, Nos. 1 and 3 from plots which had not received any manure, and No. 2 from a manured plot, were subjected to distillation. The results obtained were:

No. 1. Ammonia in dry soil.....0.00962 per cent.
No. 2. Ammonia in dry soil.....0.00765 per cent.
No. 3. Ammonia in dry soil.....0.00367 per cent.

The persistency with which the ammonia continued to come over, showed that it was probably being formed during the distillation and was not originally present as free ammonia, or as ready formed ammonia salts. In order to obtain as much evidence as possible regarding the occurrence of free ammonia in this soil, a fresh portion of sample No. 1, was taken and subjected to distillation with the addition of ammonia-free-water alone. The distillation was, as in the previous cases, permitted to proceed very slowly until two and a half litres of distillate were collected. There were still traces of ammonia coming over. The ammonia obtained equalled 0.00211 per cent. of the dry soil. The comparatively abundant evolution of ammonia in the early stages of the distillation with magnesic oxid, and the decided quantity yielded upon distillation with pure water, prove the presence of both ammonical salts and free ammonia in this soil, and the samples show that the amount of them was not dependent upon the manure added to the soil one year previous to the time that they were taken. I interpret the formation of ammonia salts and free ammonia in this soil, as indicating unfavorable biological conditions. The sample numbered 1 in this series is from that section of the plot which I have described elsewhere as a paludal soil. Its reclamation was not at this time complete. I may be mistaken in this view, but I believe it to be the explanation, and that the larger quantity of ammonical salts and free ammonia were due to the greater resistance this soil had presented to the ameliorating effects of cultivation.

§ 86. The examinations made of the ground waters, not only strengthen but extend this view. The ground waters show not only ammonia, but large amounts of nitrites, indicating a probable reduction of nitrates in some zone of the soil. The presence of ammonia in the upper portions of the soil is probably the most suspicious of all of our facts, as it seems to indicate a slow oxidation, and brings the zone of denitrification to the very surface.

### VOLATILE ACIDS IN THE SOIL.

§ 87. The conditions obtaining in this soil being such that acid fermentations might take place, an attempt was made to determine the quantity of such acids, if any were present. Two samples of soils were examined for volatile acids; one had received manure and the other had not. The sample which had received manure yielded volatile acids, other than hydrochloric, equal to 1.3 c. c. of one hundredth normal soda solution. The one which had not received manure yielded volatile acids corresponding to 10.30 c. c. of the soda solution. These are exceedingly minute quantities and their only possible value is a qualitative one, suggesting that one of the effects of the manure added was to lessen the amount of these acids in the soil by modifying the character of the changes taking place within the soil.

### NITROGEN AND NITRATES IN THE SOIL.

§ 88. Less has been done with this subject than appears desirable. My excuse is, that I have tried to study this subject in connection with the ground water, rather than with the soil, because there is no material and permanent accumulation of the nitrates in the soil, where it receives water enough, either as rainfall or as irrigation, to remove them more or less nearly at the same rate at which they are formed in the soil.

§ 89. The samples in which the total nitrogen was determined are comparable in a general way only, owing to the fact that the soil is very varying, and that the samples were not taken from the same places in the plot. This variability in the soil is shown with greatest certainty in the amounts of potash in the different samples, these amounts varying much more than can justly be attributed to analytical errors. The series of samples in which I have made such determinations may serve as a measure of the changes which the cultivation of this soil had effected in the time elapsing between the taking of the samples. The nitrogen determinations for the year 1897 have not been taken from the table of "Analyses of Soils, General Samples," but were made on special samples. The samples for 1899 are sufficiently described as manured and not manured, the manure having been applied in 1898, one year before the samples were taken.

TABLE XIX.—TOTAL NITROGEN IN THE SOIL.

| *1897.* | *Per cent.* | *1899.* | *Per cent.* |
|---|---|---|---|
| Sample A | 0.0920 | No. 3, not manured | 0.0935 |
| Sample B | 0.0945 | No. 3, manured | 1.1700 |
| Sample C | 0.0829 | No. 2, not manured | 0.1355 |
| Sample D | 0.0819 | No. 2, manured | 0.1295 |
| Sample E | 0.1382 | No. 1, not manured | 0.1316 |
| Sample F* | 0.1081 | No. 1, manured | 0.1312 |

§ 90. The samples have been arranged in this table so that those representing the same general sections stand as nearly opposite each other as possible, but they are not identical.

§ 91. The samples were taken in the same month of the year, and, so far as seasonal influences upon the nitrogen content are concerned, are comparable. The water received in 1899 was greater than in 1897. The general effect indicated is an increase of nitrogen for the whole plot.

§ 92. No effort was made to follow the formation of nitrates in the soil from day to day, or from week to week, but the amount of this substance eliminated in the ground water was determined weekly for the seasons of 1897-98-99 and 1900. The nitrates have been determined in but a single series of soil samples, representing the first and second two inches of the soils which had received no manure. The water-soluble, analyses of which have already been given, was determined in the same set of samples. The results are given in parts per million of the air dried soil.

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* Sample F is the subsoil.

### TABLE XX.—NITRATES IN THE SOIL.

| | *Water-Soluble.* | *Nitrogen.* | *Nitric Acid.* | *Potassic Nitrate.* |
|---|---|---|---|---|
| A—First two inches.... | 39,314 0 | 7.075 | 31.746 | 50.930 |
| B—First two inches.... | 7,513 0 | 36.062 | 161.814 | 259.598 |
| C—First two inches.... | 20,544.0 | 12.326 | 55.308 | 88.730 |
| D—First two inches.... | 8,000.0 | 19.200 | 86.152 | 138.214 |
| A—Second two inches.. | ...... | Trace | Trace | ...... |
| B—Second two inches.. | 3,890.0 | 0.389 | 1.745 | 2.800 |
| C—Second two inches.. | 8,130.0 | 1.626 | 7.296 | 11.705 |
| D—Second two inches.. | 8,640.0 | 2.073 | 9.306 | 14.929 |

§ 93. This indicates that, at the time these samples were taken, a very small percentage of the total nitrogen existed in the soil in the form of nitrates, and that the first two inches of this soil was at the time very much richer in nitrates than the second, also that different portions of the plot contained very different amounts of these salts.

### DO SOIL SAMPLES ABSORB NITROGEN ON KEEPING?

§ 94. The most of the nitrogen determinations given in this bulletin were made on fresh samples, but occasionally we found it desirable to check a determination on an old sample, one that had been in the sample room for one or more years. The samples are kept with ordinary care, but not always sealed. The samples which suggested this question had been carefully stoppered and kept two years, but had not been sealed. In order to answer this question, a sample was taken and the nitrogen determined in duplicate. The remaining portion of the sample was dried as usual, bottled, corked and kept in the laboratory for fifteen months and the nitrogen redetermined in duplicate. The average of the first two determinations was 0.1058 per cent., that of the last two 0.1066 per cent. The difference is 0.0008 per cent., which is possibly to be attributed to analytical differences, rather than to the absorption of nitrogen in any form from the atmosphere of the laboratory. If, however, we accept the analytical results as correct, they show that the sample gained a quantity of nitrogen, due to increase of micro-organisms, corresponding to 28 pounds per acre, taken to a depth of one foot.

### HUMUS IN THE SOIL.

§ 95. The humus in this soil is not especially low, as is the rule with our soils in general. The earlier determinations being slightly under one per cent., while the later ones average about one and one tenth per cent., a gain of about three tenths of one per cent. I thought that the physical condition of the soil and the presence of so large an amount of soluble salts would probably modify the character of the humus to a sufficient extent to cause some marked changes in properties or composition sufficient to justify its analysis. This was not found to be the case. The humus is very much like other humus, and is much more like the humus of the Southern and Eastern States, as given by Hilgard, than the humus of the prairie soils of the arid regions, which are supposed to be rich in nitrogen, carrying, according to Hilgard and Jaffa, as high as 18.5 per cent.

§ 96. A quantity of soil was treated as usual for the preparation of humus, extracted with ammonia and the solution precipitated by acidulation with hydrochloric acid. The precipitated humus was washed and dried. It formed a black mass with a strong vitreous lustre and conchoidal fracture. Its reaction was acid with litmus. The precipitated humic acids alone were preserved. The portion soluble in dilute hydrochloric acid and water was neglected, as we thought to obtain the whole of the soluble humic substances by evaporating the ammoniacal soil extract to dryness and examining it, but it was found to contain so much ammonic chlorid that the results were unreliable. It seems to be a difficult matter to wholly avoid this error when handling larger quantities of soil. The results obtained indicate a very much higher percentage of ash in the ammoniacal extract than in the precipitated humus, but on the other hand a materially lower percentage of carbon.

The elementary analysis of the precipitated humus resulted as follows:

TABLE XXI.—ELEMENTARY ANALYSIS OF PRECIPITATED HUMUS.

| | *Per Cent* | *Per Cent.* |
|---|---|---|
| Carbon | 41.787 | 45.727 |
| Hydrogen | 4.804 | 5.267 |
| Nitrogen | 5.536 | 6.051 |
| Oxygen | 39.254 | 42.955 |
| Ash | 8.619 | ...... |
| Total | 100.000 | 100.000 |

I have deducted the ash and given the carbon, hydrogen, etc., in parts per hundred to make their quantitative relation more evident, not to indicate that they form a definite compound. It is noticeable that the percentages throughout are almost identical with those given for humocienic acid obtained by precipitation as the lead salt from a solution prepared from a sample of Russian black earth.

### HUMUS AS A SOLVENT.

§ 97. The ash probably forms an integral part of this precipitated humus, that is the humus carried this inorganic part in such a state of solution that it retained it when thrown down by the dilute hydrochloric acid. The total sulfur present equalled 0.44 per cent. of the precipitated humus, equal to one and one tenth per cent. of sulfuric acid (anhydrid). The potash taken into solution by the four per cent. ammonia equalled 0.385 per cent. of the humus dissolved. The ash obtained from the filtered ammoniacal solution, by evaporation and incineration, is rich in lime, that from the precipitated humus contains only a very slight trace of it. The ash from both, the ammoniacal solution of humus and the humus precipitated from it, is relatively rich in phosphoric acid.

§ 98. We made an attempt to determine the ash carried into solution by the extraction with ammonia. The results were not satisfactory. The solutions were all filtered repeatedly, but owing to the intense color of the solutions we could not feel assured that some of the variations in our results might not have been due to a turbidity in the solution. Our results indicated roughly one per cent.; this is probably too high, but it suffices to show that a very considerable portion of the whole mass of soil is soluble in this ammoniacal humus solution.

§ 99. Authors have insisted upon the value of humus as a solvent for the inorganic constituents of plant food in the soil. Free ammonia and ammonic salts are probably present in small quantities, as previously shown, and we have in the humus, dissolved out of the soil by a dilute ammonia solution, phosphoric acid, sulfuric acid, potash, lime, iron and an abundance of silicic acid, which are not only food for the cultivated plants, but also for the micro-organisms which we believe effect the change of the nitrogen in the humus into nitric acid, respectively into nitrates, rendering it also available food for the plants. This seems an important function to attribute to humus, amounting in but few instances to more than one and a half per cent. of the soil, and yet it is justified. Our method of treatment or extraction does not faithfully represent the soil conditions, and therefore exaggerates its importance. This is probably less true than it appears to be, for the acids and bases forming the salts of the soil are not in the fixed and quiescent condition in which we usually think of them. On the contrary, there are certainly as many, and possibly more, changes going on than there would be in a mixture of the same salts in simple aqueous solution, and we know that there would be many. We have seen that there is probably free ammonia and ammoniacal salts in the soil, both of which aid the humus in its action by favoring its solution. The phosphoric acid extracted with the humus was determined at the beginning of the experiment and again after three crops had been grown on the plot. The results are shown in the following tables of analyses.

### SOME RESULTS OF THREE SEASONS' WORK.

§ 100. The plot had received but little cultivation before I began my experimentation with it, and was in such bad condition that a part of it was so good as useless for any agricultural purpose. That this was not due to any lack of plant food is indicated by the chemical analyses and also by its subsequent deportment under cultivation.

§ 101. The analyses of the samples taken at the beginning of the experiment may be summarized as follows:

TABLE XXII.—ANALYSES OF SOIL AT BEGINNING OF EXPERIMENT.

| SOIL, SAMPLES TAKEN 1897. | | Nitrogen. Per Cent. | Potash. Per Cent. | Phosphoric Acid. Per Cent. | Humus. Per Cent. | Phosphoric Acid in Humus. Calculated on Soil. Per Cent. |
|---|---|---|---|---|---|---|
| A | Spring | 0.0937 | 1.495 | 0.112 | 0.815 | 0.0384 |
| | Fall | 0.0938 | 1.528 | 0.086 | 0.712 | 0.0333 |
| B | Spring | 0.0882 | 1.003 | 0.064 | 0.945 | 0.0205 |
| | Fall | 0.1022 | 0.978 | 0.128 | 0.910 | 0.0345 |
| C | Spring | 0.0882 | 1.443 | 0.081 | 0.736 | 0.0296 |
| | Fall | 0.1015 | 1.457 | 0.115 | 0.740 | 0.0396 |
| D | Spring | 0.0959 | 1.443 | 0.061 | 0.660 | 0.0288 |
| | Fall | 0.1083 | 1.372 | 0.099 | 0.846 | 0.0294 |
| E | Spring | 0.1295 | 0.876 | 0.070 | 0.808 | 0.0486 |
| | Fall | 0.1191 | 0.936 | 0.138 | 1.030 | 0.0537 |
| F* | Spring | 0.1040 | 0.854 | 0.054 | 0.574 | 0.0384 |
| | Fall | 0.0996 | 0.750 | 0.122 | 0.502 | 0.0334 |

* F is a subsoil corresponding to soil E.

§ 102. The samples, "Spring" and "Fall," represented in the above table were not taken by the same person, nor were they taken so nearly from the same spot that they can be considered as duplicates, still the agreement throughout is as close as can be expected, except in the case of the phosphoric acid. The analyses were made by the same person, so that the personal equation is eliminated, but the differences in the phosphoric acid are great, varying from 60 to 126 per cent. of the lower percentage found. It is possible that this variation between the spring and fall samples may be in the sampling, either in the field or in the laboratory, but every care was exercised to get this entirely correct. Duplicate analyses were made on most of these samples and good agreement was obtained, so that after making every allowance for errors in the analytical work and in the sampling there is a difference in favor of the samples taken in the fall. That the whole of the phosphoric acid present went into solution, there can be no doubt. We have examined the insoluble residues obtained from these digestions and have been unable to find any phosphoric acid. I have no explanation to offer.

The only remnants of the crop which could have been present in the fall samples were the fine roots which we could not remove, and such leaves as might have fallen and decayed during the season, all others were removed from the field. With these explanations, we must abide by our results even if there is a difference of 126 per cent. in the amount of phosphoric acid in practically the same soil, sampled in the spring and fall of the same year.

§ 103. It is not a matter for surprise that samples taken three years later, after the refuse of several crops and a liberal amount of manure had been incorporated with the soil, should show differences, indicating an improvement in the soil. The subsoiling, deep plowings, and the continued cultivation, together with the fact that the ground was left thrown up into rather high and rough ridges during the winters, exposing the deeper portions of the soil to the effects of the winter seasons—all tend to mix and improve the soil; but there is only one thing which has added any mineral matter to the soil, that is the application of the manure, which was made to alternate sections of the plot, as has been stated elsewhere.

Samples taken in the autumn of 1899 gave the following results:

TABLE XXIII.—ANALYSES OF SAMPLES OF SOIL TAKEN IN 1899.

| NUMBER OF PLOT. | | Nitrogen. Per Cent. | Potash. Per Cent. | Phosphoric Acid. Per Cent. | Humus. Per Cent. | Phosphoric Acid in Humus. Calculated on Soil. Per Cent. |
|---|---|---|---|---|---|---|
| 3..... | Manured | 0.1152 | 1.1700 | 0.1343 | 1.1000 | 0.0767 |
| | Not manured | 0.0935 | 0.9990 | 0.1215 | 1.0500 | 0.0735 |
| 2..... | Manured | 0.1295 | 1.3030 | 0.1567 | 1.0600 | 0.0607 |
| | Not manured | 0.1355 | 1.0994 | 0.1695 | 1.2550 | 0.0255 |
| 1..... | Manured | 0.1312 | 0.9540 | 0.1215 | 1.2800 | Lost |
| | Not manured | 0.1316 | 0.8493 | 0.1727 | 1.0900 | 0.0670 |

These numbers, 3, 2 and 1, manured and not manured, do not correspond exactly to A, B, etc. The five sections A, B, C, D and E, were made into six sections to study the effects of manure upon the crop and soil. No. 3 manured corresponds to part of A, while No. 3 not manured corresponds partly to A and partly to B, and so on. The plot was 600 feet long, and the manured and not manured sections were each 100 feet long. The samples were taken from the middle of the respective plots at the end of the season and nine months after the application of the manure.

The results indicate an increase in the humus present, but the analyses do not show conclusively that this was due to the application of manure, though the indications are that it had a perceptible effect. The results in regard to the phosphoric acid are difficult to bring into harmony with the facts as recorded or with one another, but the general results are in the same direction as those obtained from the samples taken in the autumn of 1897, namely, an increase. The increase in the nitrogen is not very pronounced, but seemingly quite general. The most marked result, however, recorded in the last table is the increased extent to which the phosphoric acid present in the soil can be extracted with the ammoniacal solution of the humus. It is entirely out of the question to attribute this large percentage of the phosphoric acid found in the humus solution to any turbidity which, owing to the dark color of the solution, might have passed through the filter and escaped detection. I regret that I did not examine the hydrochloric acid with which the soil was washed to determine how much phosphoric acid was removed by it. An inspection of the table shows that from 14 to 60 per cent. of the total soluble phosphoric acid was found in the ammoniacal humus solution.

§ 104. If we recall the amount of nitrogen found in the precipitated humus, about 5.5 per cent., we will see that the observation made on the phosphoric acid is also applicable to the nitrogen, only in a different degree. The humus contained from 14 to 60 per cent. of the former, but 40 or more per cent. of the latter.

The manure which was applied to this soil was analyzed, the results, together with some observations on its effects, etc., are given in Bulletin 58, pp. 13, 18, 36, *et seq.*

The sulfuric acid was determined in the samples taken in 1899, giving for No. 3, manured and not manured, 1.320 per cent. and 0.350 per cent.; for No 2, 0.333 and 0.633 per cent.; for No. 1, 0.683 and 0.314 per cent. If we compute this into sodic sulfate, as we have done elsewhere, it will be seen that the sulfates have either been removed or carried down into the soil beyond the reach of our sample, and either is an improvement.

§ 105. The results of this experiment are readily recognizable in the improved condition of the soil. The figures given as representing the composition of the samples taken in the autumn of 1899, may be right or wrong, but the improvement in the soil is much more pronounced than any analytical results can indicate, and after all of our seeking after facts and explanations, we are fully satisfied that there is much in the aggregate effect, whether it has been produced by moisture, æration, frost or sunshine, that has escaped our analysis, and while it is perfectly patent, it is not subject to clear and definite formulation. The application of manure produced some effects which we have noted at some length in Bulletin 58, especially those upon the crop, and we have incidentally stated that the salts in the ground water were influenced by the same, but we have acknowledged an effect, by stating that it improved the mechanical condition of the soil, which we fail to explain, because we do not recognize in what this actually consists. There are certain bold features in this improved condition which we readily perceive, but we cannot tell to what agents this improvement is to be attributed, nor the degree in which any particular agent has participated.

### ANALYSES OF SOME COLORADO SOILS.

§ 106. I append a table of hitherto unpublished analyses of some soils from this State. These analyses were made some years ago by Mr. Chas. Ryan, under the direction of Dr. D. O'Brine, my predecessor.

There is no description or data of any kind given with the analyses. The record does not even show the locality from which the samples came more specifically than somewhere within a Colorado county. As a matter of fairness, I feel it due to Dr. O'Brine to state that, according to my information, he is not at fault for this, but that, owing to a bit of mistaken economy, he was not able to take the samples as he wished to, and did not obtain the data, whose lack detracts so materially from an otherwise commendable piece of work.

§ 107. The history of some of the samples is know, but so far as the record shows, there is nothing to indicate whether the samples are of virgin or highly cultivated garden soils, whether they are samples taken from excavations in city streets, or have been scratched from between the rocks of the hills.

The presumption was, and ought still to hold, in spite of the few exceptions of which we have definite knowledge, that the samples fairly represent the virgin soils of the State. If they do not, it is to be regretted that this work has been done to such little purpose.

## TABLE XXIV.—ANALYSES OF SOME COLORADO SOILS.

| COUNTY. | Insoluble. | Silicic Acid, Sol. | Sulfuric Acid. | Carbonic Acid. | Chlorin. | Phosphoric Acid. | Potash. | Soda. | Lime. | Magnesia. | Ferric Oxid. | Aluminic Oxid. | Manganic Oxid. | Moisture. | Ignition. | Total. | Nitrogen. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Arapahoe ..... | 69.79 | 7.05 | 0.05 | 0.05 | 0.07 | 0.08 | 0.16 | 0.54 | 3.25 | 0.03 | 2.69 | 10.03 | .... | 2.16 | 3.98 | 99.93 | 0.10 |
| Archuleta ..... | 72.48 | 4.05 | 0.13 | 0.54 | 0.04 | 0.20 | 0.26 | 0.35 | 1.31 | 0.08 | 2.29 | 9.90 | .... | 2.79 | 5.45 | 100.56 | 0.19 |
| Baca .......... | 63.00 | 7.44 | Tr. | 1.28 | 0.04 | 0.05 | 0.22 | 0.20 | 2.51 | 0.66 | 2.35 | 7.48 | .... | 5.00 | 9.25 | 99.48 | 0.16 |
| Boulder ....... | 70.68 | 3.90 | 0.14 | ... | 0.06 | 0.16 | 0.75 | 1.97 | 0.41 | 0.06 | 6.38 | 7.79 | .... | 3.10 | 4.68 | 99.99 | 0.20 |
| Boulder ....... | 67.50 | 10.00 | 0.22 | 0.35 | .... | 0.14 | 0.45 | 0.95 | 2.25 | 0.85 | 2.04 | 6.96 | 0.09 | .... | 8.28 | 100.09 | 0.11 |
| Chaffee ....... | 69.01 | 5.06 | 0.39 | .... | 0.02 | 0.05 | 0.17 | 0.95 | 2.60 | 1.14 | 1.57 | 10.31 | .... | 2.33 | 6.33 | 99.95 | 0.26 |
| Cheyenne ..... | 72.57 | 6.14 | 0.63 | .... | 0.03 | 0.04 | 0.30 | 0.25 | 1.02 | 0.56 | 0.22 | 8.88 | .. | 2.80 | 7.16 | 100.60 | 0.12 |
| Clear Creek... | 65.50 | 5.00 | 0.10 | ... | 0.04 | 0.02 | 1.69 | 1.34 | 0.96 | 0.75 | 7.08 | 8.32 | .... | 3.14 | 6.17 | 100.11 | 0.27 |
| Conejos ....... | 70.24 | ..... | 0.02 | 0.38 | 0.03 | 0.06 | 0.68 | 1.98 | 1.46 | 0.44 | 2.94 | 5.07 | .... | 3.50 | 13.10 | 99.90 | 0.23 |
| Costilla ....... | 78.50 | 1.27 | 0.39 | 0.01 | 0.06 | 0.07 | 0.26 | 2.31 | 1.65 | 0.14 | 1.42 | 8.03 | .... | 2.17 | 4.57 | 100.85 | 0.18 |
| Custer ....... | 59.85 | 2.33 | 0.63 | 7.55 | 0.02 | 0.02 | 0.49 | 0.37 | 9.39 | 0.83 | 1.24 | 1.58 | .... | 1.81 | 12.96 | 99.07 | 0.11 |
| Delta..... .... | 76.77 | 1.56 | 0.11 | 1.45 | 0.05 | 0.01 | 0.45 | 0.18 | 2.03 | 0.83 | 4.50 | 8.40 | .... | 1.96 | 1.87 | 100.17 | 0.08 |
| Douglass...... | 82.04 | 0.08 | 0.20 | 0.02 | 0.07 | 0.03 | 0.37 | 0.51 | 0.24 | 0.28 | 2.54 | 8.34 | .... | 1.42 | 3.10 | 99.24 | 0.13 |
| Eagle ......... | 73.67 | 1.80 | .... | 3.49 | 0.09 | 0.03 | 0.10 | 0.16 | 5.32 | 0.91 | 2.51 | 5.55 | .... | 1.34 | 5.04 | 100.01 | 0.09 |
| Elbert......... | 86.35 | 0.69 | 1.19 | 0.48 | 0.04 | 0.01 | 0.46 | 0.93 | 0.12 | 0.42 | 1.54 | 3.83 | .... | 1.34 | 2.66 | 100.06 | 0.12 |
| El Paso . .... | 74.37 | 2.13 | 0.06 | 1.68 | 0.05 | 0.01 | 0.20 | 0.70 | 0.28 | 0.21 | 1.97 | 10.57 | .... | 2.23 | 5.52 | 99.98 | 0.23 |
| El Paso ....... | 79.35 | 5.35 | 0.42 | 0.31 | .... | 0.49 | 0.35 | 0.30 | 0.65 | 0.25 | 1.25 | 4.25 | 0.08 | .... | 7.09 | 100.15 | 0.20 |
| Fremont ..... | 74.65 | 2.70 | 0.49 | 0.46 | 0.06 | 0.04 | 0.49 | 0.12 | 1.49 | 0.29 | 3.75 | 10.90 | ... | 1.49 | 2.97 | 99.90 | 0.07 |
| Garfield ....... | 72.68 | 5.20 | 0.44 | 0.21 | 0.06 | 0.14 | 1.38 | 0.63 | 0.71 | .... | 2.07 | 8.27 | . .. | 2.82 | 5.32 | 99.93 | 0.16 |
| Grand ......... | 72.01 | 6.09 | 0.53 | 1.00 | 0.05 | 0.05 | 0.37 | 0.22 | 0.70 | 0.16 | 1.06 | 3.88 | .... | 3.80 | 11.03 | 100.95 | 0.25 |
| Gunnison ..... | 67.00 | 5.51 | 1.46 | .... | 0.05 | 0.01 | 0.75 | 0.86 | 2.05 | 0.58 | 2.86 | 10.24 | .... | 2.30 | 6.21 | 99.98 | 0.13 |
| Jefferson...... | 60.72 | 10.56 | 0.99 | .... | 0.05 | 0.01 | 0.57 | 0.78 | 2.34 | 0.17 | 6.17 | 9.77 | .... | 3.06 | 4.72 | 99.98 | 0.12 |
| Kiowa......... | 70.53 | 7.36 | 0.41 | .... | 0.03 | 0.06 | 0.27 | 0.31 | 5.67 | 0.02 | 1.55 | 7.35 | .... | 3.55 | 2.92 | 100.03 | 0.24 |
| Kit Carson.... | 73.11 | 7.11 | 0.61 | 0.02 | 0.07 | 0.03 | 0.41 | 0.30 | 3.00 | 0.66 | 1.93 | 6.06 | .... | 3.57 | 3.14 | 100.02 | 0.14 |
| Las Animas... | 77.72 | 5.32 | 0.45 | 1.01 | 0.04 | 0.90 | 0.25 | 0.11 | 1.55 | 0.11 | 2.93 | 4.70 | .... | 1.66 | 3.70 | 100.45 | 0.06 |
| La Plata...... | 75.74 | 7.15 | 1.14 | .... | 0.02 | 0.10 | 0.76 | 0.22 | 0.93 | 0.13 | 2.59 | 4.06 | .... | 1.48 | 5.66 | 99.98 | 0.16 |
| Larimer ...... | 65.35 | 6.38 | 1.44 | 4.90 | 0.03 | 0.08 | 0.12 | 0.56 | 6.72 | 0.28 | 2.18 | 5.96 | .... | 1.80 | 4.10 | 99.90 | 0.08 |
| Larimer ...... | 81.50 | 5.67 | 0.31 | 0.40 | ... | 0.28 | 0.42 | 0.36 | 1.15 | 0.35 | 2.17 | 4.10 | 0.03 | .... | 3.25 | 99.99 | 0.10 |
| Larimer ... .. | 67.47 | 7.88 | .... | 1.96 | 0.09 | 0.09 | 0.15 | 0.35 | 3.43 | 0.56 | 2.01 | 7.30 | .... | 2.88 | 5.75 | 99.92 | .... |
| Lincoln .... . | 78.43 | 10.74 | 0.36 | .... | 0.03 | 0.15 | 0.24 | 0.71 | 0.48 | 0.50 | 1.79 | 3.90 | .... | 1.17 | 2.00 | 100.50 | 0.12 |
| Logan ........ | 78.08 | 8.30 | 0.05 | .... | 0.05 | 0.03 | 0.70 | 0.46 | 1.36 | 0.18 | 1.76 | 6.19 | .... | 1.57 | 2.02 | 100.12 | 0.11 |
| Mesa ... ...... | 72.49 | 10.41 | 1.66 | 1.65 | 0.03 | 0.11 | 0.11 | 0.50 | 3.43 | 0.70 | 2.45 | 3.36 | .... | 1.00 | 2.11 | 100.01 | 0.01 |
| Montrose ...... | 66.00 | 1.75 | 1.23 | 5.32 | 0.06 | 0.04 | 0.78 | 0.87 | 6.81 | 0.08 | 2.68 | 6.25 | .... | 2.45 | 5.76 | 100.04 | 0.05 |
| Montezuma ... | 77.60 | 2.98 | 1.35 | .... | 0.06 | 0.05 | 1.29 | 0.55 | 0.38 | 1.49 | 2.13 | 6.56 | .... | 2.64 | 2.93 | 99.99 | 0.09 |
| Morgan ....... | 84.94 | 2.04 | 0.39 | 0.06 | 0.05 | 0.04 | 0.56 | 0.86 | 0.19 | 0.05 | 0.99 | 5.53 | .... | 1.33 | 2.67 | 99.60 | 0.16 |

TABLE XXIV.—ANALYSES OF SOME COLORADO SOILS—(Continued).

| COUNTY. | Insoluble. | Silicic Acid, Sol. | Sulfuric Acid. | Carbonic Acid. | Chlorin. | Phosphoric Acid. | Potash. | Soda. | Lime. | Magnesia. | Ferric Oxid. | Aluminic Oxid. | Manganic Oxid. | Moisture. | Ignition. | Total. | Nitrogen. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ouray ......... | 55.12 | 6.55 | 0.97 | 6.54 | 0.05 | 0.19 | 1.95 | 0.48 | 8.16 | 0.27 | 1.86 | 10.85 | .... | 1.48 | 5.69 | 100.16 | 0.13 |
| Otero .......... | 80.23 | 3.03 | 0.50 | 1.15 | 0.09 | 0.14 | 0.91 | 1.52 | 1.76 | 0.16 | 2.38 | 4.45 | .... | 1.55 | 3.25 | 100.12 | 0.12 |
| Park .......... | 79.55 | 2.67 | 0.54 | .... | 0.05 | 0.07 | 0.65 | 0.45 | 2.33 | 0.55 | 0.95 | 2.10 | .... | 3.04 | 7.90 | 99.85 | 0.32 |
| Pitkin......... | 70.50 | 3.95 | 0.85 | 3.16 | 0.03 | 0.08 | 0.46 | 0.81 | 2.27 | 0.28 | 2.89 | 4.60 | .... | 2.54 | 7.62 | 100.04 | 0.26 |
| Phillips ....... | 73.43 | 4.00 | 1.86 | 1.98 | 0.04 | 0.25 | 0.15 | 0.75 | 1.45 | 1.89 | 2.31 | 5.68 | .... | 2.96 | 3.78 | 100.53 | 0.08 |
| Prowers....... | 69.90 | 8.10 | 0.60 | .... | 0.03 | 0.09 | 1.69 | 0.54 | 1.44 | 0.79 | 2.78 | 5.94 | .... | 2.65 | 5.79 | 100.36 | 0.13 |
| Pueblo ........ | 75.84 | 5.11 | 0.10 | 0.36 | 0.04 | 0.08 | 0.22 | 0.16 | 1.02 | 0.54 | 3.71 | 5.66 | .... | 2.19 | 4.75 | 99.36 | 0.13 |
| Rio Blanco.... | 69.88 | 4.35 | 1.12 | 1.95 | 0.04 | 0.18 | 0.78 | 0.27 | 1.45 | 0.43 | 2.75 | 7.13 | .... | 2.56 | 6.64 | 99.55 | 0.24 |
| Rio Grande ... | 76.03 | 4.64 | 0.67 | .... | 0.09 | 0.09 | 0.90 | 0.77 | 1.55 | 0.95 | 5.40 | 5.09 | .... | 1.48 | 3.00 | 100.66 | 0.09 |
| Routt ......... | 67.04 | 6.14 | 0.66 | .... | 0.04 | 0.20 | 0.69 | 0.57 | 1.21 | 0.53 | 3.33 | 6.73 | .... | 3.56 | 9.20 | 99.90 | 0.24 |
| Saguache ..... | 65.59 | 9.46 | 1.10 | .... | 0.09 | 0.11 | 0.26 | 0.99 | 1.64 | 0.63 | 3.60 | 5.33 | .... | 3.97 | 7.41 | 100.18 | 0.24 |
| San Miguel ... | 69.61 | 5.28 | 0.47 | 1.19 | 0.04 | 0.06 | 0.11 | 0.44 | 2.10 | 0.67 | 3.38 | 6.08 | .... | 3.60 | 7.30 | 100.33 | 0.31 |
| Sedgwick ..... | 69.43 | 5.87 | 1.20 | 2.47 | 0.08 | 0.80 | 0.33 | 0.84 | 3.46 | 0.82 | 2.21 | 5.40 | .... | 2.83 | 6.34 | 100.58 | 0.11 |
| Washington .. | 73.33 | 6.80 | 0.41 | 1.02 | 0.02 | 0.05 | 0.56 | 0.16 | 1.04 | 0.28 | 2.01 | 5.56 | .... | 3.56 | 4.75 | 99.53 | 0.12 |
| Weld .......... | 79.76 | 6.36 | 1.13 | .... | 0.05 | 0.11 | 0.54 | 0.16 | 1.88 | 0.42 | 2.43 | 3.52 | .... | 1.48 | 2.52 | 99.86 | 0.07 |
| Weld ..... .... | 78.17 | 7.75 | 0.26 | 0.28 | 0.05 | 0.31 | 0.38 | 0.30 | 0.97 | 0.40 | 3.01 | 3.96 | 0.04 | .... | 4.42 | 100.26 | 0.13 |
| Yuma ......... | 67.90 | 5.31 | 1.03 | 0.11 | 0.02 | 0.29 | 1.53 | 0.84 | 3.43 | 1.15 | 4.88 | 7.55 | .... | 1.43 | 4.83 | 100.30 | 0.07 |
| *Otero†........ | 74.27 | 10.50 | 0.05 | 0.68 | 0.02 | 0.04 | 0.41 | 0.78 | 1.38 | 0.71 | 4.34 | 2.43 | 0.17 | 1.44 | 3.54 | 100.76 | 0.08 |
| Otero‡ ........ | 84.06 | 5.88 | 0.04 | 0.31 | 0.01 | 0.04 | 0.26 | 0.33 | 0.60 | 0.22 | 3.38 | 1.66 | 0.22 | 0.74 | 2.42 | 99.98 | 0.05 |
| Otero§ ........ | 78.22 | 9.87 | 0.06 | 0.27 | 0.02 | 0.02 | 0.01** | 0.70 | 1.05 | 0.46 | 4.24 | 1.36 | 0.22 | 0.89 | 2.55 | 99.94 | 0.06 |

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* Analyses of melon soils from Fowler, taken Jan. 27, 1899, analyst F. C. Alford. Digestion with acid sp. gr. 1.115 for 10 hours.

† Humus 0.14. ‡ Humus 0.08. § Humus 0.10.

** Examination of this sample shows very little feldspar in it.

# SUMMARY.

§ 108. The "alkali" salts in the soils and waters of Colorado are essentially mixtures of the sulfates of lime, magnesia and soda.

§ 109. The soils of the eastern slope of the Rocky Mountains and of the plains lying to the east in Colorado, have in general a very similar composition, as shown by the composition of the soil mass.

The mineralogical composition of these soils is very similar, the principal variation being in the ratio of the quantities of the minerals present.

§ 110. The surface soils of this section of Colorado probably owe their mineral constituents to a common source, the schists and granites of the Colorado range.

§ 111. The feldspar, orthoclase, an almost universal constituent of our soils, serves as a source of potash and also of hydrous silicates under ordinary cultural conditions.

§ 112. The readiness with which the chemical reactions take place and their character, as indicated by the salts present in the ground waters, probably have a direct and important bearing upon the fertility of the soil. The loessial soils of the plains agree with the ordinary prairie soils in the chemical composition of their mass and in the general results of the agricultural analysis, but not in the mechanical analysis.

§ 113. The analyses of the whole soil mass and of the different portions of the fine earth, suggest important differences between the unchanged rock particles in the soil and the finer portions which have suffered change or are the products of alteration.

§ 114. The aggregate amount of soluble salts per acre whose movement is effected by the water falling on or supplied to the surface, or by its evaporation from the surface, is large; we make it nine tons in one instance. The application of water, irrigation, may carry the soluble salts so deep into the soil that a long time may be required for them to come near to the surface again.

§ 115. The chemical analyses give us no hint of the very great improvement which was effected in this soil by three, really four, years experimentation with it. Our question was one of conditions and not of composition, so far as its purely agricultural features were concerned.

§ 116. The water-soluble in the soil and the incrustations formed upon the soil are very different in composition.

§ 117. The incrustations are formed by the evaporation of water from the surface of the soil, which, owing to the deportment of the solutions of these salts toward capillary action, and the chemical instability of the hydrated salts themselves, effects their separation from the soil solutions.

§ 118. The water-soluble in the soil is not identical with ground water solutions, probably due to reactions dependent upon the relative masses, which react upon each other within the soil and during the extraction.

§ 119. The reactions near the surface of the soil are quite different from those more remote. This is indicated by the solutions yielded by samples taken to depths of two and four inches.

§ 120. There is, in the samples of soil examined, both free ammonia and ammoniacal salts, which we interpret as indicating unfavorable biological conditions, which view is materially strengthened by the nitrates in the ground waters.

§ 121. There is a significant gain in the total soil nitrogen during the time of the experiment, which may have been favored by, but was not dependent upon, the application of manure.

§ 122. The nitrates in the first two inches of this soil are from nine times to two hundred times as great as in the second two inches, corrobative of the suggested reduction in certain zones of the soil.

§ 123. Air dried soil samples can be kept for a year or more with ordinary precautions, without material change in their nitrogen content.

§ 124. The humus in this soil is nearly as abundant as in average Eastern soils, and we were unable to find anything about it markedly different from ordinary humus. It is unlike the humus of arid soils, in that it is not so rich in nitrogen as they have been found to be.

§ 125. The solutions of the humus carried relatively very large amounts of silicic acid, phosphoric acid, potash and lime. The precipitated humus did not carry much lime.

§ 126. The effect of the cultivation, manuring, etc., for three seasons, may be summed up by stating that the store of plant food in the surface soil, taken to a depth of ten inches, was actually increased. This, however, was the lesser part of the improvement, the greater part lay in the betterment of the general conditions, whose best features cannot be shown by chemical analysis, or expressed in any formula.

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**Bulletin 66.** **Sept., 1901.**

The Agricultural Experiment Station

OF THE

Agricultural College of Colorado.

# RELATION OF BOVINE TO HUMAN TUBERCULOSIS.

G. H. GLOVER.

# TUBERCULIN TESTS OF THE COLLEGE HERD.

B. C. BUFFUM.

PUBLISHED BY THE EXPERIMENT STATION
Fort Collins, Colorado.
1901.

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PLATE I. KATE—JERSEY COW, APPARENTLY HEALTHY, BUT BADLY DISEASED WITH TUBERCULOSIS.

# PART I.

## REVIEW OF THE ARGUMENTS OF THE RELATION OF BOVINE TO HUMAN TUBERCULOSIS.

BY GEORGE H. GLOVER.

The recent test of the College herd with tuberculin and the consequent discovery of tuberculosis among cattle which were supposed to be in perfect health has led to some controversy; on the one hand by those who, because of their knowledge gained by actual observations and experiments, and who having been trained to think and reason to logical conclusions, are warranted in expressing themselves; and on the other hand by those who are not so warranted.

One thing in particular, more than any other, has inspired the issuing of this bulletin, viz: The evidence everywhere extant, that since the stand recently taken by Dr. Koch, there has settled upon the public a determined disposition to belittle the whole matter and throw precautionary measures to the wind. We urge upon all the warning that the difference between human and bovine tuberculosis has not yet been settled finally, and that precautionary measures for preventing the spread of the disease by butter and milk cannot be safely abandoned. It is one of the misfortunes accompanying the deliverance of such an uncompromising thesis as that by Dr. Koch that obscurantists of every dye make it responsible for conclusions which are not warranted by the facts in the case. It cannot be too strongly emphasized that even if it be proven that bovine tuberculosis is not communicable to the human race, the necessity for the most scrupulous cleanliness in the management of cows and their milk production is as great as ever. This incident coupled with the perfectly reliable information which we possess that a large percentage of the dairy cows in Colorado supplying milk to our towns and cities (especially the latter) are consumptive, and that it is yet far from proven that this disease is not communicable to human beings by the use of such milk; and further, lest the recent stand taken by Dr. Koch results in a criminal laxity or indifference: have together inspired the issuing of this bulletin. It is not claimed that we have made any new or startling discoveries: the work among the College herd, so far as it has gone, has in every instance corroborated our claims (and which are in harmony with a great majority of the foremost investigators in this line of research) and the conclusions arrived at by reliable authorities are here compiled in as brief a manner as possible, hoping to accomplish something toward arousing the masses from their lethargy relative to the importance of this serious condition as affecting the animal wealth and the possibility of its being a prolific source of disease in the human family.

In the annual report of the Veterinary Science Department of the College, the assertion is ventured that the public in general in judging of veterinary science is prone to look upon it from a purely commercial (and in a lesser degree humanitarian) standpoint and do not take cognizance of its broader sphere of usefulness, viz: what the science is doing for the health and lives of the people themselves. It is in keeping with this thought that we venture a step further and assert that the educated veterinarians are among the leaders in the van now vigorously prosecuting the research that is being made in regard to the relation of human to bovine tuberculosis.

Tubercular consumption is one of the most dreadful and unfortunately, most common diseases of mankind. People of all ages or circumstances, and environments, regardless of climate, nationality, or degree of civilization, are subject to infection, if exposed under proper conditions. None are immune, and the present conditions prevailing, it looks as if we are doomed to become a sickly, consumptive race, and that its ravages must eventually almost wipe the human race from the face of the earth.

The greatest good to humanity will be accomplished along the line of preventing disease and while the prevailing medical thought now, both human and veterinary, is absorbed in new remedies, and is alive with keen expectancy as to the possibilities of sero-therepy, (which seems almost beyond conjecture) yet, after all, we must admit that prophylaxy (prevention of disease) is of vastly more importance than the discovery of new cures.

## NOT A NEW DISEASE.

History from the earliest times has been replete with accounts of this "great white plague" and the theories advanced to account for its etiology and pathology have only been equalled in variety by the persistency with which they have gone wide of the mark.

At one period it would be considered contagious, at another this would be thought improbable, again several of the local manifestations of this disease would be looked upon as separate and distinct diseases; at other times it has been confounded with diseases that had no relation to it whatever. It seems strange, but it is nevertheless true, that while this disease has been known as affecting the lower animals, and a scourge in man (now claiming ten per cent. of the death rate) during all these centuries comparatively nothing was accomplished in working out its etiology or pathology until within the last fifty years Villimian and Koch have placed the matter on a sound basis.

## IS A GERM DISEASE.

Long before any suspicion existed as to the relation of bacteria to fermentation and disease, various scientists, at different times, had suggested that resemblance existed between the phenomena of certain diseases and fermentation, but the idea that a virus or contagium might be something of the nature of a minute organism, capable of spreading and reproducing itself, had never been thought of. The first vague notion in this direction was no doubt the ferment theory of Cagniard-Latour in 1828. In 1837, Schwann showed that fermentation and putrefaction were intimately associated with the presence of organisms derived from the air. By 1862 Pasteur had buried forever that "will-o-the-wisp" spontaneous generation and repeated and extended such experiments and proved the way for a complete explanation of the anomalies.

From 1870 onward the "germ theory of disease" had passed into general acceptance and now has become an assured fact, and in a sense has revolutionized the theories of disease and treatment in that now a persistent war is waged on the micro-organisms which excite the disease, and is not based altogether upon symptomology. Robert Koch first succeeded in demonstrating and isolating the specific bacillus of tuberculosis and achieved its artificial cultivation by the use of blood-serum.

## TRANSMISSIBILITY.

The origin of the germ theory of disease and the discovery of the specific bacillus of tuberculosis are but parts of an old story now relegated to history, but when we look up the subject of the transmission of these germs from one animal to another, including man, we are at first surprised and then astounded at the seriousness of the conditions actually existing, and the grave possibilities which the tireless investigation by scientists may yet have in store for us.

## NOT CURABLE.

Favorable climatic influence will often stay the progress of the disease for a time at least, but no climate or therapeutical agent has ever been discovered which can in the true sense be called a cure. If ever anything is accomplished in either curing or preventing the disease it will most likely be in the direction of sero-therapeutics, but this is conjectural to say the least.

## RELATION OF BOVINE TO HUMAN TUBERCULOSIS.

That tuberculosis is transmitted from one animal to another, and more especially from the cow to other domesticated animals, has been repeatedly proven so that it is considered a waste of time now to rehearse them. The whole subject is summarized by Dr. John Repp in an article read before the Iowa Tuberculosis Convention in this way: "Enough has been done to prove beyond the peradventure of a doubt, that tuberculosis may be transmitted through the milk and the food structures of tuberculous animals, to the animals that consume these products or are inoculated with them, upon this all students of the subject agree. This much has been proven, but these facts do not decide the important question at issue, viz: whether or not tuberculosis is transmitted from animal to man, nor would they if they were multiplied ad infinitum, they only furnish a basis from which we may reason, for this purpose they are invaluable, as they establish the premise that the meat and milk of animals do, at times, contain living virulent tubercle-bacille."

If some of the incredulous will show the faith of their convictions by submitting themselves to a few "hypoes" of bovine bacillus-tuberculosis, or by voluntarily injecting a few of the same, it will supply the last link in the chain of evidence necessary to convict the cow of transmitting the disease through her milk and meat to her human benefactors.

As there is little probability of anyone offering in good faith to sacrifice themselves for the cause of science, let facts be submitted which, while circumstantial, are sufficient to lead us beyond the range of probability, to the very verge of absolute certainty. Our certain knowledge on the following may be analyzed as follows:

## TRANSMISSION OF TUBERCULOSIS FROM ONE ANIMAL TO ANOTHER NOT INCLUDING MAN.

*1st, by Meat.*—Experiments, by their positive results, demonstrate that tuberculosis is transmitted in this way, both by artificial inoculation with the muscle juice of tuberculous animals, as well as by feeding the diseased tissue.

*2d, by Milk.*—This has been as fully demonstrated by a long series of experiments consisting of the inoculating of different animals with tuberculous milk, both from cows with diseased udders as well as those not so diseased, and further by the feeding of calves, rabbits, pigs, etc., with milk from tuberculous cows.

## TRANSMISSION TO MAN.

There is, as previously stated, for reasons well understood, no opportunity to secure evidence by artificial methods. By natural methods the evidence consists of recorded observations, which have been made by close observers, covering a period of many years, of people who have used the milk and meat of tuberculous cattle. Dr. John Repp has gathered some statistics bearing on this point which are most interesting, as follows: "Oliver reports that in a young ladies boarding school, five girls, the children of healthy parents, died of tuberculosis of the intestines. The cow which had for many years supplied the school with milk was found to have generalized tuberculosis including the udder.

"Two daughters of a Scotch family of good health, who were brought up on milk of tuberculosis cows, died of tuberculosis. Two sons in the same family, who did not use the milk remained healthy." "Stang reports the case of a five-year-old boy of sound parentage and ancestry, who died of tuberculosis. The cow whose milk this boy used was found badly tuberculous." "Demme reports the case of four infants in the Children's Hospital at Berne, the offspring of sound parents, that died of intestinal and mesenteric tuberculosis. He was able to exclude all other sources of infection and to decide that they had been infected by the ingestion of the milk of tuberculous cows." "Hills mentions the case of a child twenty-one months old of a friend of his, which drank the milk of a highly tuberculous cow for one week while on a visit to his uncle, and three months later this child died of intestinal tuberculosis. Other sources of infection could be excluded. A second child brought up on sterilized milk is still healthy." "Hills also reports the death of a boy four years old, at Yonkers, New York, from tuberculor meningitis. The infection was traced to the milk of two cows of whose milk the boy had drank and which proved on autopsy to be tuberculous." "Ernest reports the death of three children of one family, from tuberculosis. These children had used the milk of a cow which later died of advanced tuberculosis including the udder.

"Stalker and Niles report that five persons, between twenty and thirty years of age of healthy ancestry, died of tuberculosis within a period of two years. On the farm where these deaths occured they found seventeen cattle suffering from tuberculosis, and other cattle had previously died of this disease.

"Leonhardt reports the death from tuberculosis of the meninges, intestines and mesentary, of two children fed on the milk of a tuberculous cow. Sontag reports the case of a six-months-old child of healthy parents, which died of tuberculosis and which had been fed on the milk of a tuberculous cow. Hermsdorf has reported the case of a child, dead of intestinal tuberculosis, which had been fed on the milk of a tuberculous cow. Rich reports that a young man of healthy parents, who died of tuberculosis, had used plentifully of the milk of a herd of seventy-four cattle, sixty-five of which were tuberculous, some of them markedly so. Also another young man of the same family died of tuberculosis two months later. Rich destroyed eighty cattle out of the herd, that is about 90 per cent, of the entire herd. Also a young woman died of tuberculosis, and a month later the cows, whose milk she had used, died of advanced tuberculosis."

"Thorn reports that twenty-two physicians out of 339 practicing in Ohio, replied in the affirmative to the question, 'have you been able to trace any cases of tuberculous disease to the milk of unhealthy cows?' and that thirty-three replied in the affirmative to the question, 'Have you had reason to suspect the origin of tubercular disease in older children or adults to be in the meat or milk supply?'

This series of experiments and observations has been selected from literature with the greatest care, any reports which appeared not to be well authenticated or of a doubtful nature being excluded."

"Further circumstantial evidence is at hand in the fact that such large numbers of the bottle fed children die of the abdominal form of tuberculosis, and while, in some countries, the death rate of adults shows a marked decrease, the tuberculosis of children, and especially infants, is on the increase."

As previously stated, if we could but supply the one missing link, viz: whether the bacillus of tuberculosis is pathogenic for man, we would have our chain of evidence complete, and a positive demonstration would be our reward and the question would be no longer doubtful. The cases which I will now quote, from Dr. Repps' report, show conclusively that tuberculosis in the bovine species can be conveyed to man through one channel at least. "Tscherming, of Copenhagen, attended a veterinarian who had cut his finger in making a postmortem on a tuberculous cow. The wound healed but there still remained a swelling which soon ulcerated and refused to heal so that the whole tumefied mass had to be cut out. The microscope revealed the distinct tuberculous process and the presence of the characteristically staining bacilli." Pfeiffer attended at Weimar, a veterinarian named Moses, thirty-four years old, of good constitution and without hereditary disposition, who, in 1885, cut his right thumb deeply in making a post-mortem on a tuberculous cow. The wound healed, but six months later the cicatrix still remained swollen and in autumn, 1886, the man had pulmonary tuberculosis with bacilli in his sputa and death occured in two and one-half years after the wound. Post-mortem revealed tuberculosis of the joint of the wounded thumb, and in the lungs extensive tubercles and vomicæ." "Law reports that a young veterinary friend of his who was inoculated in the hand in opening a tuberculous cow, suffered from a tumefaction of the resulting cicatrix with tubercle-bacilli."

Rich reports that a man cut his finger on a spicule of bone, while making a post-mortem examination of tuberculous cows, and that in a few weeks he developed a tuberculous joint, and a few months later showed unmistakable signs of phthisis.

Ravenel reports the case of a veterinarian who cut the knuckle of his finger while making post-mortem examination of a tuberculous cow. The wound healed badly, remained swollen and showed decided tendency to ulcerate. Removal of cicatricial mass was practiced the tissues sent to him for examination. They showed typical tubercular lesions with giant-cell formation.

"I am well acquainted with this case myself and believe it to be an undoubted case of direct. transmission of tuberculosis from cow to man by inoculation. This veterinarian told me that he did not become alarmed about the wound on his finger until he noticed a swelling and tenderness of the lymphatic glands on the muscle of the elbow."

The statistics gathered on this point are not many, but are exceedingly valuable as far as they go.

## BOVINE TUBERCLE MORE VIRULENT THAN THE HUMAN VARIETY.

From the scattered records of inoculation experiments, both early and recent, relative to the degree of virulency of of the tubercle bacilli of man and the bovine species, the conclusion arrived at I can best express by the following quotation: "To sum up the matter in a few words, it may be said that bovine tubercle has been shown to be more virulent than the human variety for cattle, sheep, goats and rabbits, while no distinction has been shown in the case of horses, pigs, cats and dogs.

## DOMESTIC COW THE NATURAL HARBINGER OF THE BACILLUS TUBERCULOSIS.

Dr. G. A. Johnson, in an article read before the Sioux Valley Medical Association, takes the position that in the bovine species we have the natural hosts of the bacillus tuberculosis. His argument is so fair and altogether unique that while it is entirely foreign to the prevailing idea of the medical fraternity, it is certainly worthy of serious consideration. He states his proposition in this way. "Tubercular lesions, wherever found, are the direct results of the action of the tubercular bacillus; and further, that the domestic cow is the natural harbinger of this bacillus; or in other words, tuberculosis was primarily a disease of the bovine species and is found in man and other animals as a result of transmission brought about through the ability of the tubercular bacillus to adapt itself to the various conditions as found in the various animals.

He reasons from analogy that a careful study of the geographical distribution of tuberculosis reveals the fact that all people who use the milk and flesh of the domestic cow (the and inbred cow) as food products are more or less afflicted with tuberculosis, and further, that there is usually a very uniform ratio between the quantities of such foods consumed and the prevalence of the disease among the people.

On the other hand all of those people who do not use the food products of the domestic cow are comparatively free from the disease.

Prof. E. F. Brush, M. D., of Mount Vernon, N. Y., states as follows: "This insidious and delusive disease is not the result of civilization as is supposed. Barbarous and semi-civilized races are afflicted as severely as many of the most advanced civilized races." Neither geographical position nor climatic conditions are a factor in the distribution of pulmonary phthisis. Every known part of the globe, with a few isolated areas excluded, is a habitat of the disease. After several years of close study of the affection and consulting all accessible statistics and the habits of the people where the disease prevails, the only constanly associated factor is found, in my opinion, in the inbred bovine species without any regard to the social position of a community or its geographical habitation, terrestial or atmospheric condition. If a community is closely associated with inbred cattle, tuberculosis is prevalent. In the fifteenth annual report of the State Board of health of New York, is found the following: "Human tuberculosis is co-extensive with bovine tuberculosis. Broad generalization of our laws and knowledge gives a close parallelism between the numbers of dairy cows and the prevalence of tuberculosis in the human race. Countries that have few or no cattle, or in which the herds are mainly kept in the open air, and are therefore largely protected from the disease show, as a rule, little tuberculosis in man."

Dr. G. A. Johnson, in substantiation of his argument, has found the conditions prevailing in different countries relative to this matter as follows:

*Europe*—Cattle have existed and tuberculosis has prevailed in man for centuries.

*Australia*—Tuberculosis was so rarely seen in early days as to lead to the idea that the climate was incompatable with the disease, but with the advent of cattle raising consumption appeared among the people and has been gradually increasing.

*New Zealand*—Among the native Maories phthisis was unknown previous to the settlement of the English, and they possessed no cattle, but since that time tuberculosis has become a veritable scourge. Hirsch has said, "In my opinion the death rate from phthsis will keep on increasing in that locality if the breeding of cattle is not properly regulated by law."

*South Africa*—The coast tribes of Africa have been inbreeding cattle for centuries, and the natives have been tuberculous, while the tribes in the interior have had no cattle, because of the Tsetse fly which stings and kills them, have always been free from consumption.

*Madagascar*—The flesh and milk of cattle has been the principle diet of the native and they have been severely afflicted.

*North American Indians*—The native American Indians were always free from consumption until Uncle Sam began dealing out meat and cattle to them. Their habit of eating any and all parts of the carcas, often without cooking, has aggravated the conditions for the most favorable transmission of the disease and they have become consumptive.

*The Esquimaux*—Dr. Johnson has well expressed it when he says, "The Esquimaux has his dogs and reindeer, but no tuberculosis, while the indian has his dogs and beef and is seriously afflicted with tuberculosis." On the other hand, it is found that the Indian is no more susceptible to the disease than is the Esquimaux, for when the latter is brought in contact with the white man and his cow he readily contracts the disease, etc.

*Italy*—The people are tuberculous, notwithstanding they have one of the balmiest climates of the earth.

*China*—Notwithstanding their dense population, consumption is rare, because the lower classes, which constitute the mass of the population, get very little or no meat or milk. And so he goes on with a review of the different people of various countries and islands of the globe, showing in each and every instance that those people who use the milk or meat of cattle are consumptive and just in proportion as they use said products and those who do not possess cattle at all are entirely free from it.

*Climate*—Immunity does not exist in any climate, or among any race of people. And while high and dry climates like Colorado are beneficial in staying the progress of the disease, yet it prevails in various sections from the torrid to the frigid zones.

*Altitude*—Altitude has nothing to do with the distribution of the disease, for we find it from the sea coast to the regions of the highest mountains. Dr. Johnson says that "certain peoples inhabiting the Dead Sea basin, which is between 100 and 200 feet below the sea level, are free from tuberculosis, whereas it is more or less prevalent among most people inhabiting the mountainous regions of Europe and America."

*Civilization*—The disease does not follow in the wake of civilization, for some of the savages and semi-civilized races are seriously afflicted.

*Density of Popuation*—As previously indicated, China and India, two of the most densely populated countries, are comparatively free from tuberculosis, and in many of the rural districts of Europe and America the disease prevails.

*Filth and Poor Sanitation*—This has nothing to do with the distribution of the disease for we find it all the way from the wigwam to the palace. The fact remains that all these various conditions simply hasten to retard the morbid process, and not one of them can be said to be a constant factor in the distribution of the disease. The old argument of heredity has long ago fallen to the ground and been trampled to the dust, for new cases of consumption are constantly coming to view, where there cannot be traced any hereditary taint.

The only constant factor seems to be the milk and meat of the bovine species, and we certainly consider this argument worthy of serious consideration.

# CONCLUSIONS.

1. The position taken by Dr. Koch is of inestimable value, whether right or wrong, as there has been nothing new but this conclusion placed before the medical and veterinary profession during the past decade, and it has aroused everybody from their lethargy and encouraged discussion and experiment as never before.

2. It is unwarrantable to assume that, because of the low virulence of human bacilli for cattle, that the reverse is true. It has been repeatedly shown that bovine bacilli are more virulent than the human. Bovine bacilli being easily transmitted to rabbit, horse, dog, pig and sheep, and in short, to almost every quadruped on which they have been tried, makes it highly improbable that man is not included in the list; and until this is disproven by actual experiment upon the human, it will not be wise to relax prophylactic measures.

3. Dr. Koch has been grossly misrepresented since his London Congress address. He says, among other things, 'I have one word and only one word to say, and that is what I said in London. That word is 'experiment!'" I would send it to my brother practitioners the world over. The time is past when we may be guided with either certainty or profit by statistics. Nothing short of actual dealing with actual conditions will avail. We demonstrated that human tuberculosis was incapable of transmission to cattle. We have now to lend ourselves to the reverse proposition.

"I did not mean to recommend the abandonment of comprehensive and expensive systems of regulation, prevention and inspection that is now in operation.

"We are well on the road to victory over consumption. The final triumph is denied only by those who are unwilling to sacrifice their hobbies and work together to the common end."

# PART II.

## TUBERCULIN TESTS OF THE COLLEGE HERD.

BY B. C. BUFFUM.

Our investigation of tuberculosis among the cattle belonging to the College is in line with what has been done by other Experiment Stations of prominence which have been doing live stock work. There is nothing startling or new, perhaps, in our findings, but we feel the matter is of much importance to the public. Dealing as it does, directly with our animal wealth and indirectly, perhaps, with the public health, it is well for the Station to give to the people of the state such information as we possess. We are not indulging in personal opinions or theories, but will confine our statements to what we believe are established facts. We believe it is high time that our agricultural communities should accept the situation, and dispassionately and intelligently take such wise action as will advance their own interests and, in all probability, alleviate human suffering as well.

So much has already been done to prevent and partially cure tuberculosis, that there is no longer excuse for allowing the disease unchecked progress either among animals or men. Tubercular consumption is now known to be a preventable disease and, contrary to the general opinion, it has been demonstrated that it is curable in a large per cent of cases or, at least, that the course of the disease may be checked for many years if taken in time and properly managed. It is probably true that there are over ten million people now living in the United States who are doomed to die of this dread disease unless something is speedily done to reduce the present death rate. This may be considered a fair statement of the present status and prevalence of human tuberculosis.

Cattle seem to be more subject to tuberculosis than any other representatives of the animal kingdom, but it is hardly possible to arrive at a correct estimate of the money loss to our agricultural interests from the bacillus tuberculosis. Coupled with these two items is the supposed relation of human and bovine tuberculosis. The disease in man and in cattle has long been considered identical and in view of the many facts supporting such belief so well presented by Dr. Glover in Part I. of this Bulletin, it is well that everyone should understand the possible danger and take such precautions as will save money loss with stock, and protect against personal contagion. It is reported that Dr. Koch, before the London conference on tuberculosis, expressed the opinion that human and bovine tuberculosis are not due to the same germ. If reports are true, Dr. Koch believes that there is proof that human tuberculosis cannot be transmitted to cattle and, while not demonstrated, he thinks bovine consumption not transmissible to man. Dr. Koch discovered the true cause of tuberculosis and fully demonstrated the germ nature of the disease. He is one of the world's greatest authorities and his opinion should be given much weight. However, scientists are often misquoted and a simple statement of a failure to produce certain expected results in an experiment is twisted into a quotation from an authority, that it is an impossibility to produce the results. Newspaper misquoting and reportorial enlargement of scientists' statements are often mistaken for true science. It opens the way for ridicule and prejudice and does much to retard the acceptance of scientific facts. If Dr. Koch failed to transmit tuberculosis from man to cattle, or if he has discovered differences in the germs from animals and men which led him to doubt the identity of the two forms of the disease, it does not necessarily follow that the expression of this doubt is a statement of fact that there is one form of the disease in cattle and another in man and that they are never transmissible from one to the other. Dr. Koch thought that his lymph or tuberculin was a cure for tuberculosis. It was a wonderful discovery and a most important one, but because it failed to cure human tuberculosis is no reason for rejecting the careful scientific work of the man. The principle of using the toxin or poison produced by a germ to destroy the germ, or its power to live in the sytem, was established by Jenner when he introduced vaccination against small pox and is successfully used as a cure of the disease in diphtheria. One of our state papers (The Eastonville World) takes a sensible view of the present statements of Koch, that he doubts the general infection of man with bovine tuberculosis, and points out the fact that we need not plunge into the use of unsanitary milk, butter and beef because a scientist has expressed such a doubt. Before

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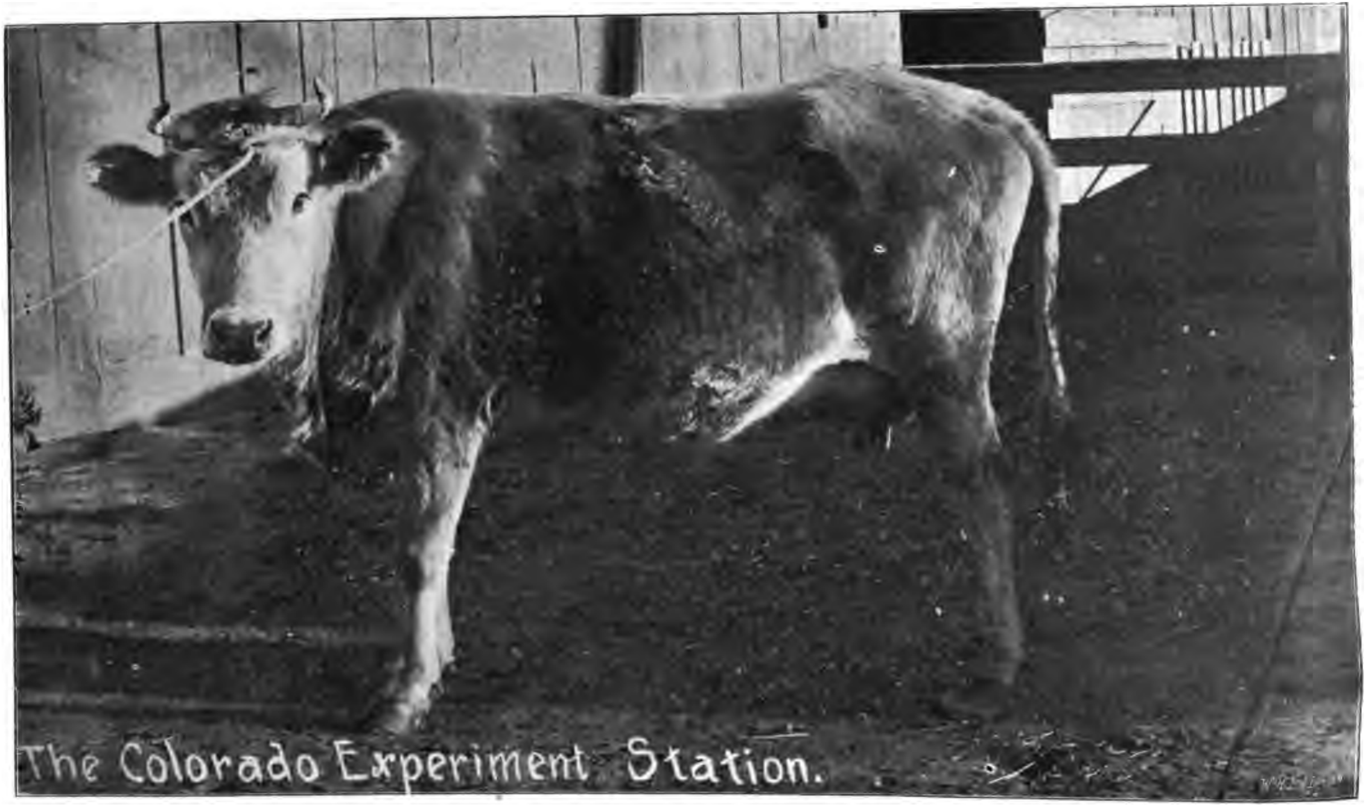

PLATE II. COUNTESS LEE—JERSEY COW WITH GENERALIZED TUBERCULOSIS.

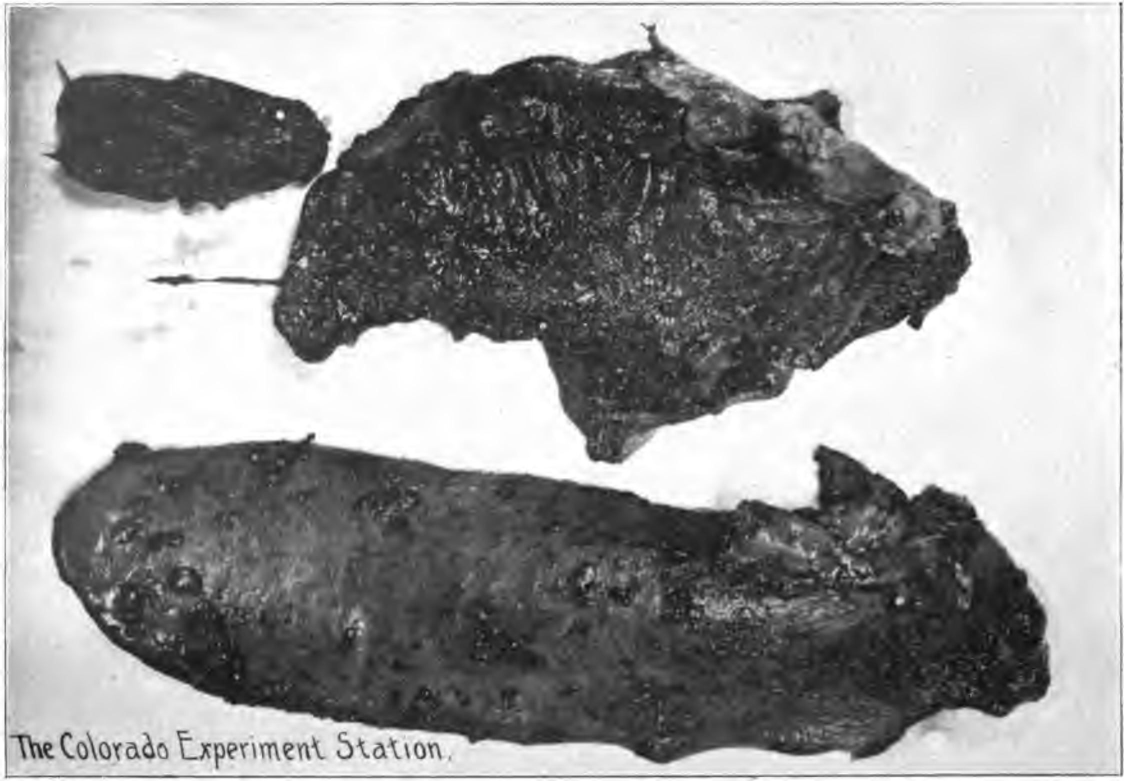

PLATE III. SECTION OF LEFT LUNG OF DISEASED COW FILLED WITH TUBERCLES AND CALCAREOUS DEPOSIT. SPLEEN OF DISEASED COW SHOWING LARGE TUBERCLES ON SURFACE.

leaving this part of the discussion let me state that there has been a large amount of scientific investigation which goes to prove that human tuberculosis can be transmitted to cattle by direct inoculation, and there is little doubt of its transmissibility from animal to animal or from one kind of animal to another.

If Dr. Koch's announcement is true, it is a most important discovery. However, so much evidence has accumulated to prove that men contract bovine tuberculosis that scientists are slow to accept this new theory of Koch's and will not do so without abundant proof.

The following quotations as made by the "Literary Digest" are of interest:

**From the Philadelphia Press.**

"The chief evidence of the transmission of tuberculosis from cows to human beings has rested on the cases of children. The strongest proof was summed in a report lately made to the British Medical Council that 'The mortality from tuberculosis in early childhood is not decreasing as at other ages, and the opinion that this is due to infection by milk appears well founded."

"Meanwhile, laboratory evidence accumulated that the human and bovine bacillus were not identical in shape, tests or increase. Cattle are relatively unsusceptible to human tuberculosis. It is extremely probable that Dr. Koch has carried this to full proof and developed the difference to be one of species. If, however, tuberculosis cannot furnish bacilli which gives human beings the disease, the cattle bacilli render cattle diseased. Infection once begun infects the entire herd. Unless people chose to eat diseased meat, and drink milk with bovine tubercle containing, as was found in Boston, 810 million germs to the tumbler, tuberculous cattle must continue to be sternly destroyed."

The following from the "Medical News" of New York:

"The belief that bovine tubercle bacillus is incapable of inducing tuberculosis in man is, of course, by no means new. For years there have been advocates of this side of the question. As a matter of fact, there is abundance of clinical evidence which indicates this capacity. Thus, Tscheving, of Copenhagen, in 1888, reported a case in point. The sufferer was a veterinary surgeon who wounded his finger while making an autopsy on a tuberculous cow. Local tuberculosis in the wounded part developed in a short time. Lefevre collected other equally striking examples which would be very difficult of explanation if our present view is incorrect."

The introduction to this report by Dr. Glover gives the above cases and presents abundant reason for suspecting tuberculous cattle. It will take nothing short of absolute proof to convince that bovine tuberculosis is not dangerous to man. It is to be devoutly hoped that this is so, as it would greatly simplify the problem of ridding both man and cattle of the worst disease with which either is afflicted. Meanwhile, we should not cease using judicious caution and our researches are doubly interesting. The evidence against bovine tuberculosis has been sufficient excuse for all the laws and regulations enforced against it.

At the close of the British Congress on tuberculosis, before which Professor Koch delivered his paper, a series of resolutions were adopted, among which appears the following, as published in Science, Aug. 1901:

> "That in the opinion of this Congress and in the light of the work that has been presented at its sittings, medical officers of health should continue to use all the powers at their disposal and relax no effort to prevent the spread of tuberculosis by milk and meat."
>
> "That in view of the doubts thrown on the identity of human and bovine tuberculosis it is expedient that the government be approached and requested to institute an immediate inquiry into this question which is of vital importance to the public health and of great consequence to the agricultural industry."

There were over 2,500 members at this Congress including many of the world's foremost scientists.

## THE TUBERCULIN TEST.

Within the past year the restrictions of this government on the importation of tuberculous cattle has given rise to vigorous protests on the part of men actuated by selfish interests. Our own people submitted to like restriction without complaint, but enforcing such regulations against Canadian cattle has given rise to what we believe are unwarranted attacks on the reliability of the tuberculin test which is used to determine whether or not cattle are tuberculous.

We think it unfortunate that some of our leading stock journals have published attacks on the test, which are calculated to mislead the public in regard to its efficiency and value. The highest authorities state that tuberculin is perfectly harmless to healthy cattle when properly administered as a test for tuberculosis. They are also agreed that it is a means of detecting the disease which is of great value and sufficiently accurate to be practically infallible. Because it gives fever to diseased animals or occasionally fails to produce its effect on such advanced cases that the disease can be found by physical examination does not seem sufficient reason for condemning it as a diagnostic agent. It is believed that it does not fail to detect the disease in more than one-fifth of one per cent. of cases which are not far advanced in their course, and in our experience the disease has been found in every case which responded to the test.

Tuberculin is a glycerine extract of the toxin produced by the bacillus tuberculosis, but it contains no living germs which can communicate the disease. The normal temperature of an animal is obtained, then a small quantity of the tuberculin is injected hypodermically so it will be absorbed into the blood. If the animal is diseased the tuberculin causes a rise in temperature of 2 degrees or more in 8 to 16 hours, and sometimes a swelling and soreness where the injection was made. It should be used under the direction of a veterinarian or physician, or someone who has used and understands the method of applying the tuberculin and observing the results.

## WHY WE TESTED THE COLLEGE HERD.

Our cattle had not been tested and we suspected the disease. However, we had only one animal under suspicion, and we hoped she would be the only case. Gildana, a Jersey cow about eight years old had been out of health for some months. She had the malignant catarrhal fever which was prevalent during the fall months, and did not recover as did other animals which were affected. She seemed to be passing into decrepid old age which we thought due in all probability to tuberculosis. Dr. Glover was consulted and he agreed to test the dairy herd. We did not expect to find many cases as we thought there was reason to believe that tuberculosis might not be so prevalent in our dry sunny climate as it had proved to be in more humid regions. There may have been a little personal pride in the thought that our cattle, which had been given the best of care under the most favorable conditions, would be unusually healthy. As we will show later this idea was not without some foundation in fact. But tuberculosis is a disease which leaves its victim hopeful and in good cheer and one about which the novice should not jump at conclusions. We guessed that Gildana had tuberculosis, but we guessed wrong, for she did not respond to the test and is now believed to be healthy, while other cows in the herd which to all appearances were healthy, were found to be veritable pest houses of infection.

Again, because cattle form so large a part of human food; because they are subject to many diseases fatal to man, and because cattle products, as milk and butter, are used in the raw state they are a constant menace to the public health. It is important then that the greatest care and sanitary precautions should be used in handling cattle and their products. Outside of the danger to man there is the item of financial loss from the presence and spread of disease among our stock. These are sufficient reasons for every cattle owner applying every test and attention which will insure keeping only healthy stock. Dr. Bang, the great Danish authority, has succeeded in having laws passed which makes sanitary precautions compulsory in Scandinavia, and already enough has been done in Europe to show that tuberculosis may be materially decreased by proper sanitary control of tuberculous subjects among both animals and man. In Denmark national laws make it compulsory to heat all milk to 185 degrees F. before it is sold, or before butter is made from it.

In Germany tuberculous persons are required to take the sanitary treatment prescribed and they find that tuberculosis is decreasing under these laws. Many of our states have legislative regulations for stamping out tuberculosis among cattle, and some of them are extreme in requiring the slaughter of all reacting animals. If human and bovine tuberculosis prove to be the same disease, it would seem that this method would be the surest and quickest way of removing the greatest of all dangers to human life, but because of the uncertainly, we are probably not ready at the present time to adopt such drastic and expensive measures. However, enough is known at the present time so no one is excusable for using milk or butter from cows which have not been given a bill of health and demonstrated free from tubercle, and no stockman is excusable for harboring and breeding the disease in his herd.

## RESULTS OF THE TESTS.

Three tests have been made of the cattle on the College farm, by Dr. Geo. H. Glover, veterinarian. The first on December 8, 1900, was of all the cows being milked in the dairy, consisting of seven Jerseys and one Shorthorn and also one Shorthorn which had lost her calf and had not been doing well for some time. Table I gives the result of this test, showing the normal temperatures determined before inoculation and the rise in temperature after injection. The maximum temperatures and total rise of reacting animals are shown in bold faced type. Unless the rise in temperature was more than 2.5 degrees it was not considered proof of infection. It will be seen that of the nine animals tested five, or 56.6 per cent. reacted.

## TABLE I.

### TUBERCULIN TEST MADE DEC. 8, 1900.

### COLORADO AGRICULTURAL COLLEGE.

| No. | Name | Breed | Wt. lbs. | Age yrs. | Nrm'l Temp. °F | Max'm Temp. °F | Hours after injec'n | Rise in Temp. °F | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Young Grannie | Jersey | 1072 | 10 | 100.1 | 101.5 | 11 | 1.4 | |
| 2 | King Lee Noble | " | 1122 | 4 | 100.7 | **107.1** | 11 | **6.4** | Destroyed. Early stages of disease |
| 3 | Gildana | " | 920 | 10 | 100.3 | 101.2 | 13 | 0.9 | |
| 4 | Kate | " | 828 | 4 | 100.9 | **106.7** | 11 | **5.8** | Destroyed Had generalized tuberculosis |
| 5 | Lucy | " | 860 | 4 | 101.0 | **104.9** | 11 | **3.9** | Destroyed. Disease not advanced. |
| 6 | Lelia Rose | " | 770 | 2 | 101.3 | **105.0** | 12 | **3.7** | |
| 7 | Gildana 2nd | " | 872 | 3 | 101.4 | 101.8 | 21 | 0.4 | |
| 8 | Orchard Girl | Shorth'rn | 1376 | 5 | 100.9 | 102.2 | 8 | 1.3 | |
| 9 | Ambrosia 2nd | " | 982 | 3 | 101.7 | **106.0** | 8 | **4.3** | Destroyed. Generalized tuberculosis |

The second test, principally of the Shorthorn cattle was made January 12. The results are given in Table II. No. 1, Young Grannie; No. 2, Lee Noble; No. 3, Gildana; No. 6, Lelia Rose; No. 7, Gildana 2d, and No. 11, Ambrosia, were cows which were injected during the first test. An interesting point and one which has been urged against the test is that the Jersey, Lelia Rose, and the Shorthorn, Ambrosia, which gave reactions at the first test on December 8, failed to react to this second injection of tuberculin. It merely illustrates the fact that an injection of tuberculin renders an animal immune to the test for some time after it has been made.

The time between tests of the same animal should probably not be less than six months, and the results of a test should not be accepted unless it is known that the animals have not been injected with tuberculin for at least six months time. Therefore we did not accept the failure to react at this second test as an indication of freedom from the disease and at the post mortem Ambrosia proved to be about as bad a case as could exist and the animal continue to live, although she appeared fairly well and thrifty.

Counting out the animals tested December 8, including

## TABLE II.

### TUBERCULIN TEST MADE JAN. 12, 1901.

### COLORADO AGRICULTURAL COLLEGE.

| No. | Breed | Wt. | Age | Nrm'l Temp. | Max'm Temp. | Hours ofter injec'n | Rise in Temp. | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1 | Jersey | 1072 | 10 | 100.8 | 101.9 | 12 | 1.1 | Second test |
| 2 | " | 1122 | 8 | 101.4 | **106.5** | 18 | **5.1** | Destroyed. Had generalized tuberculosis |
| 3 | " | 920 | 10 | 100.8 | 101.3 | 5 | 0.5 | Second test |
| 4 | Shorth'rn | 900* | 2 | 102.2 | 103.3 | 9 | 1.1 | |
| 5 | " | 1140 | 5 | 101.7 | 101.2 | 9 | .......... | |
| 6 | Jersey | 770 | 2 | 101.1 | 103.0 | 11 | 1.9 | Second test |
| 7 | " | 872 | 3 | 101.8 | 101.9 | 5 | 0.1 | Second test |
| 8 | Shorth'rn | 1225* | 3 | 102.1 | 104.0 | 13 | 1.9 | |
| 9 | " | 1240* | 3 | 103.2 | 102.3 | 5 | .......... | |
| 10 | " | 1260 | 3 | 102.4 | **106.3** | 13 | **3.9** | |
| 11 | " | 1250* | 3 | 102.8 | 102.2 | 21 | .......... | Second test. Generalized tuberculosis |
| 12 | " | 1050 | 3 | 102.2 | **106.1** | 13 | **3.9** | |
| 13 | " | 1190 | 7 | 102.4 | 102.3 | 9 | .......... | |
| 14 | " | 1075 | 7 | 102.4 | 102.9 | 4 | 0.5 | |
| 15 | " | 1320 | 4 | 102.6 | 102.9 | 4 | 0.3 | |
| 16 | " | 1135 | 5 | 101.8 | 102.3 | 9 | 0.5 | |
| 17 | " | 1300* | 4 | 102.7 | 102.5 | 4 | .......... | |
| 18 | " | 1225 | 5 | 102.2 | 102.7 | 4 | 0.5 | |
| 19 | " | 1275* | 4 | 102.2 | **105.8** | 15 | **3.6** | |
| 20 | " | 1650 | 2 | 102.5 | **106.5** | 15 | **4.0** | |
| 21 | Jersey | 800 | 1 | 101.6 | 103.0 | 12 | 1.4 | |
| 22 | " | 805 | 1 | 101.8 | 103.6 | 10 | 1.8 | |

* **Estimates based on later weights.**

## TABLE III.

### TUBERCULIN TEST MADE JAN. 26, 1901.

### COLORADO AGRICULTURAL COLLEGE.

| No. | Breed | Wt. | Age | Nrm'l Temp. | Max'm Temp. | Hours after injec'n | Rise in Temp. | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1 | Jersey | 1540* | 3 | 100.8 | 101.7 | 8 | 0.9 | Bull |
| 2 | Shorth'rn | 1000* | 2 | 101.9 | 101.0 | 11 | .......... | |
| 3 | " | 1260 | 2 | 101.8 | 101.3 | 8 | .......... | |
| 4 | " | 1270 | 12 | 102.5 | 103.9 | 21 | 1.4 | |
| 5 | " | 1565 | 6 | 103.6 | 105.6 | 13 | 2.0 | |

those which reacted, there were 18 new ones tested January 12. Of the 18 animals, four, or 22 per cent. reacted. This does not include No. 8 which gave a temperature rise of 2 degrees.

While we had taken the temperatures of all the cattle, not quite enough tuberculin was obtained so a third test was made January 26. One Jersey bull and four cows were tested. (See Table III.) As none gave a rise of temperature of more than 2 degrees it was not considered sufficient to prove the disease in any of them.

## SUMMARY OF REACTIONS.

A total of 31 head were injected with tuberculin and 10 reacted, or thirty-two and one-fourth per cent. There were 11 Jerseys, of which 5 reacted, or nearly 45.5 per cent. Out of 20 Shorthorns, 5 gave definite reactions, or 25 per cent., and 2 doubtful cases in which the temperature did not rise high enough to be considered proof of disease.

There were in reality two herds of Shorthorns. The old herd which had been raised on the College farm or had been here for 8 or 9 years did not contain a diseased animal while the 5 cases were out of a herd of 12 animals which had been brought from Iowa one year before the test. Then there was 41⅔ per cent. of the Eastern Shorthorns and none of the Western animals tuberculous. While this may have been an accident, we take it as significant, and probably it indicates what may be expected in a general way. It is generally believed that Western range cattle are practically free from tuberculosis.

## POST MORTEMS.

Four of the reacting Jerseys and one Shorthorn have been killed and carefully examined. These examinations were conducted by Dr. Glover. In order to make the examinations as thorough and authentic as possible Dr. Glover secured the assistance and cooperation of Dr. L. Clark, a veterinarian of long standing and ability in the government employ, and Dr. R. McCarroll of Fort Collins. Mr. C. J. Griffith and the writer assisted with the work and took the notes. The College authorities were present to satisfy themselves that the disease was demonstrated and the class in veterinary science took an interested part. None of the cows had the disease far enough advanced to make it possible for the veterinarians to detect it by physical examination, but the diagnosis as made by the use of the tuberculin proved correct in every case and three of the five cows examined had generalized tuberculosis, i. e., nearly all the organs were diseased. In three of the four Jerseys examined tubercles were found in the udder where they were discharging into the milk. No attempt will be made to write a technical description of these post mortem examinations, but the following general notes will give the reader an idea of the amount of infection demonstrated:

*Kate.* (No. 4 in Table I.) Jersey cow, 4 years old. Reaction, 5.8 degrees. Killed and examined December 15, 1900. Carefully examined before death, but could find no evidence of disease. Cow in good condition with considerable internal fat. Had been lame and evidently suffering from effect of the injection of tuberculin since December 8. Lungs healthy except the lymphatic glands in the lungs which were hard and gritty with calcareous deposits in the tubercles. Kidney healthy, scattering tubercles size of pinhead to one-half pea, scattered over the intestines, especially the large intestine. Spleen covered with tuberculous growths. Liver with scattering tubercles and grit of small size all over surface and through the mass. Inside of womb and placenta along with umbilical cord covered with tubercles from size of grain of sand to small pea. Small tubercles found in udder. Photographs taken of cow and affected glands Carcass burned.

*King's Lee Noble.* (No. 2 in Table I.) Jersey cow, four years old. Reaction, 6 4 degrees. Killed and examined December 29, 1900. Apparently in good health. Glands in lungs and those from the mesenteries affected, but not in advanced stage of disease. Well developed tubercles in the udder where milk glands were discharging over them. Photographs taken of cow before death, and of affected glands. Carcass burned.

*Lucy.* (No. 5 in Table I.) Jersey cow, four years old. Reaction, 3.9 degrees. Killed and examined December 29, 1900. Cow apparently healthy. All organs apparently healthy, Finally small glands from the mesenteries were found with well developod tubercles in the milliary stage. (Millet-seed like excretions of calcareous matter encysted in the glands.) Photographs taken before and after death, also of glands. Carcass burned.

*Lee Noble.* (No. 2 in Table II.) Jersey cow, seven years old. Reaction, 5.1 degrees. Killed and examined January 26, 1901. Though this cow was apparently healthy, inside of carcass and organs were found to be literally covered and filled with tubercles, the principal affection being in the liver, lungs, udder, lymphatic glands, placenta and umbilical cord. Hard, gritty, calcareous deposits everywhere. Carcass burned.

*Ambrosia.* (No 9 in Table I and No 11 in Table II.) Shorthorn cow, three years old. Reaction, 4.3 degrees. Killed and examined May 4, 1901. Cow apparently in good condition, well supplied with fat and with no external evidence of the disease. She had not been eating well for some time and we had been unable to get her with calf. Had a small tumor on right jaw. Post mortem demonstrated an advanced stage of tuberculosis. Ovaries and uterus badly diseased and filled with pus from the breaking down tubercles. Beside the sex organs, the spleen, liver and intestines, along with lining of lungs and heart. were covered with surface tubercles. The lungs were very much affected, the left one being almost entirely filled with tubercles and calcareous deposits. Those who saw this dissection expressed surprise that the cow could be so generally diseased and continue to live, while in reality she had evidenced little outward sign of trouble. Photographs taken of spleen, glands and uterus. Carcass burned.

## REACTING ANIMALS NOT ALL DESTROYED.

It may be well to explain why all reacting animals were not destroyed at once. Some of them were kept for several reasons. In the first place it is a matter of some interest to determine whether tuberculous animals from the East will be cured of the disease by open air treatment when brought West. Second, it is considered possible to raise healthy calves from cows which are not badly affected, by separating them from the mother at once and putting them on nurse cows which are free from disease. Third, the cows will be useful clinical material for the instruction of students in veterinary science. The reacting animals are being kept away from healthy ones and as soon as our barn is remodeled and thoroughly disinfected we hope never to put a tuberculous animal in it. With every precaution against spreading infection the cattle will be handled for a time for experimental purposes. At the same time we will speed the day when we can say that our stock is free from disease and that there is no hereditary tuberculosis or tendency to it in any cattle at the College.

## CONCLUSIONS AND RECOMMENDATIONS.

1. While there is probably less disease in Colorado than among cattle from humid states, the disease is present in our herds and should receive attention.
2. Stockmen, especially dairymen and owners of family cows should get rid of the disease and not introduce more of it by the purchase of infected animals.
3. The tuberculin test is a reliable way of finding out whether cows are free from tuberculosis.
4. People should secure sanitary milk and disease-free butter, especially where children consume them. Milk or cream not from tested cows should be boiled before using. In ordinary practice any heat less than boiling should not be considered sufficient to kill the germs.
5. We do not know whether tuberculosis is commonly transmitted from cattle to man. The evidence that it is, as

presented in Part I of this bulletin is very strong. On the other hand so great an authority as Dr. Robert Koch thinks he has proved that human and bovine tuberculosis are different diseases.

6. In the state of our present knowledge of tuberculosis we can afford to take no chances by harboring infected animals, both because of the danger to ourselves and of the loss among our stock.

7. A cow may be seriously diseased so she will spread the infection to her calf or the rest of the herd and finally become unproductive and worthless herself without showing external signs of having a disease. The only known way of proving a cow healthy is by using the tuberculin test.

8. There is evidence to show that calves may inherit tuberculosis from their mothers, but it is generally considered that they are free from the disease when born and may be kept healthy by raising them on milk which is free from the bacilli.

9. Where apparently healthy cows which respond to the test are kept for raising calves they should be isolated and every precaution taken to prevent the spread of the disease to the rest of the herd. We found the sexual organs badly diseased in three out of five cows examined and do not think it would be safe to use the herd bull with them. In the writer's opinion the most profitable method is complete and conscientious destruction of diseased animals.

10. Cow stables should be regularly cleansed and disinfected. Good disinfectants are chloride of lime or a wash of equal parts carbolic acid and sulphuric acid mixed and diluted with twenty parts water. Sulphuric acid must be added slowly and carefully to the carbolic acid and these carefully to the water.

Bulletin 67. December, 1901.

The Agricultural Experiment Station

OF THE

Agricultural College of Colorado.

# THE DISTRIBUTION OF WATER

## POWERS AND DUTIES OF IRRIGATION OFFICIALS IN COLORADO

BY

H. N. HAYNES.

PUBLISHED BY THE EXPERIMENT STATION
Fort Collins, Colorado.

# THE AGRICULTURAL EXPERIMENT STATION

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# IRRIGATION ADMINISTRATION OF COLORADO.

1. *The State Engineer.*
   Appointed by the Governor for a term of two years.

   2. *Superintendents of Irrigation.*
      One to each of the six water divisions. Subordinate to the State Engineer. Superior to the Water Commissioners. Appointed by the Governor, term of two years.

      3. *The Water Commissioners.*
         One to each water district. Subordinate to Water Superintendent and to the State Engineer. Appointed by the Governor from persons recommended by the several Boards of County Commissioners in the counties in which the water districts extend; term of two years.

The water districts consist of "the land now irrigated or which may be hereafter irrigated from ditches taking water from the following described rivers or natural streams of the State of Colorado."

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### WATER DIVISIONS AND DISTRICTS.

1. *The Platte, or Water Division No. 1.* Consists of all the water districts consisting of lands irrigated from the North and South Platte, Big Laramie River, North and Middle Forks of the Republican, Sandy and Frenchman Creeks and tributaries.

*Water Districts.* 16 in number. Nos. 64, 1, 28, 23 on the South Platte numbering from the State line; 3 on the Cache la Poudre; 4 Big Thompson; 5 St. Vrain; 6 Boulder and Coal Creeks; 9 Bear Creek; 46 and 47 North Platte (North Park); 48 Big Laramie; 65 Republican, Sandy and Frenchman Creeks.

2. *The Arkansas, or Water Division No. 2.* Consists of water districts of lands irrigated from the Arkansas River and its tributaries, Smoky Hill, South Fork of the Republican and Dry Cimarron.

*Water Districts.* 13 in number. Nos. 11, 12, 14, 17 and 67 on the Arkansas, in order down stream; 10 Fountain Creek and tributaries; 13 Grape Creek; 15 St. Charles; 16 Huerfano; 18 Apishapa; 19 Purgatoire; 49 South Fork of the Republican and Smoky Hill; 66 Dry Cimarron.

3. *The Rio Grande, or Water Division No. 3.* Lands watered from the Rio Grande and its tributaries.

*Water Districts.* (8). Nos. 20 and 24 Rio Grande; 21 Alamosa and La Jara Creeks; 22 Conejos; 23 Rio Grande and Costilla; 25 San Luis, Sand or Medano, Big and Little Spring Creeks; 26 Saguache; 27 Tuttle, Carnero and La Garita; 35 Trinchera.

4. *The San Juan. or Water Division No. 4.* Lands irrigated by San Juan River and its tributaries.

*Water Districts.* (6). Nos. 29 and 32 San Juan; 30 Rio Las Animas; 31 Los Pinos; 33 La Plata; 34 Rio Mancos.

5. *Grand River, or Water Division No. 5.* Lands in Colorado irrigated by the Grand River and its tributaries.

*Water Districts.* (20). Nos. 28, 39, 42, 45, 51, 53, Grand River; 36 Blue River; 37 Eagle; 38 Roaring Fork; 39 Grand, Elk, Rifle and Rhone; 40 Crystal Creek, Smith's Fork and Gunnison; 41 and 68 Uncompahgre; 42 Grand, Gunnison in Mesa County; 50 Muddy and Troublesome Creeks; 59 Gunnison; 60 San Miguel; 61 and 63 Dolores; 62 Gunnison.

6. *Green River, or Water Division No. 6.* Lands irrigated bv water taken from the Green River and its tributaries.

*Water Districts.* (7). Nos. 43 White River; 44, 55, 51 and 58 Yampa; 54 Little Snake; 56 Green River.

# INTRODUCTORY.

Every person who uses water in Colorado, whether for agricultural or domestic purposes is affected by the methods of distribution of the state, or by their application.

At least two sets of administrative machinery are required to deliver water to the consumer; one under the direction of the state officials provides for the division of water from the streams to the ditches and the protection of their various rights; the other, for the carriage and distribution of water from the head gates of the ditches to the consumer.

The machinery of the state is more particularly the subject of this bulletin. The methods of distribution to be followed by the ditches, and the duties of the ditch officials, are left to the ditches themselves. These are generally provided for in the by-laws of the ditches, or by custom. It is hoped to take up the division in ditches more fully in a future bulletin.

This bulletin consists of two lectures given by Hon. H. N. Haynes of Greeley, before the Short Course for Irrigation Officials, given at the Agricultural College in the spring of 1901. Their importance concerning one of the subjects which touches closely on the agricultural welfare of Colorado justifies a wider distribution.

They give a summary useful to every consumer and to the officials themselves on the powers and duties of the State Irrigation Officials, and aside from the intrinsic importance and the value of the views of a careful legal student, the information is widely scattered and difficult of access.

To those who have been acquainted with the development of Colorado irrigation law, Mr. Haynes needs no introduction. To others, it is sufficient to say that he was one of the first to represent the state as judicial referee in decrees relating to the appropriation to ditches. In the subsequent development of Colorado law on irrigation he has been actively concerned in the settlement of almost every question of importance brought for judicial determination in Northern Colorado; and a student of irrigation law in its broader aspects.

L. G. CARPENTER, Director.

# THE DISTRIBUTION OF WATER

## POWERS AND DUTIES OF IRRIGATION OFFICIALS UNDER COLORADO LAWS.

By H. N. HAYNES.

It is the purpose of this paper to consider the powers and duties of state officials in distributing water. The American law of irrigation is yet in a formative state. It was unknown to the common law of England, from which we have borrowed the great body of our system of jurisprudence. It has been gradually building as the result of customs of the early settlers in the arid part of the United States, judicial decisions announced thereon, and the enactment of statutes, both by Congress and the several Territorial and State governments. Most of the decisions of the courts on irrigation subjects up to this time, have pertained to questions of appropriation of water from running streams, and from other sources of supply, and to controversies between rival ditch owners as to their relative rights, while comparatively little attention has been given to the matters now under consideration. So noticeable is the dearth of judicial decisions on the question of distribution of water by officials in charge, that in the two text-books on irrigation law, written respectively by Mr. Kinney and Mr. Long, the space devoted to the subject occupies but a very small fraction of the volumes.

In Long on Irrigation, which is divided into 15 chapters, but one chapter, the 12th, containing only four sections, is on the subject of public control of irrigation, and that chapter consists in the main of references to statute law. The space devoted to the same subject in Kinney on Irrigation, is about as limited.

It follows from the foregoing that little more can be said on the subject of the duties of the several water officials than to call attention to the statutes of the state prescribing their duties, to make some comments thereon with reference to practical questions likely to arise, to indicate the probable position which may be taken by the courts, and to suggest what line of policy and action should guide the officials under the statutes, to carry out their true intent and purpose, and so far as possible, to obviate the necessity of contentions and unnecessary litigation. It can readily be seen, it is difficult to go very far into this discussion without traveling into ground which is somewhat open to controversy. The lack of authoritative judicial decisions on many questions likely to arise, is necessarily a source of embarrassment in making such comments from a professional standpoint.

## EARLY LEGISLATION.

It is interesting to note that the first Legislature of Colorado Territory, on November 6, 1861, passed an act to protect and regulate the irrigation of lands, the fourth section of which, down to the proviso, reads as follows:

> **"That in case the volume of water in the stream or river, shall not be sufficient to supply the continual wants of the entire country through which it passes, then the nearest justice of the peace shall appoint three commissioners as hereinafter provided, whose duty it shall be to apportion in just and equitable proportion, a certain amount of said water upon certain or alternate weekly days to different localities, as they may in their judgment, think best for the interests of all parties concerned, and with a due regard to the legal rights of all."**

The proviso of the section excepted from its operation land on what is known as Hardscrabble Creek, a tributary of the Arkansas. In the Revised Statutes of 1868, the same section was re-enacted, except that the Probate Judge was made the official to appoint the three commissioners, instead of the nearest Justice of the Peace. In 1870, by act approved February 11th of that year, that portion of said section 4, which referred to Hardscrabble Creek, was repealed. (Session Laws, 1870, p. 158, Sec. 1.)

In 1872, there was further legislation concerning the duties of the water commissioners in the County of El Paso. It was provided that they should receive $5.00 per day when discharging their duties, to be paid by means of a tax levied by the County Commissioners, on each person using water for irrigation, in proportion to the amount of water used by each person.

In the second section of the act approved February 6, 1872, concerning irrigation in El Paso County, it was provided that the commissioners, with a due regard to prior vested rights, should establish such rules and regulations as in their judgment are necessary and proper to secure the purposes of the act, and to control the use of water for irrigation.

The third section of the act made it a misdemeanor subject to a fine and imprisonment, for a person to use water from any ditch or water course of the county to which he was not entitled, when the commissioners were controlling the same, or to hinder any commissioner in the performance of his duties.

A statute adopted February 9, 1872, applicable only to Pueblo County, required each ditch company to construct a tail ditch to return water with as little waste as possible, to the river, and made it unlawful to take more water into a ditch than was necessary to irrigate the land under it when water was scarce in the stream. The second section amended the act of 1868, by substituting one commissioner for three commissioners. The third section required in Pueblo County, before a commissioner should be appointed by the Probate Judge, that a majority of the riparian owners on each stream, should sign a petition, requesting an appointment to be made, mentioning whom they preferred. (Session Laws, 1872, p. 144.)

The General Laws of 1877, which was a compilation of previous general statutes, as well as of those enacted by the first general assembly of the State of Colorado, contained the fourth section of the chapter concerning irrigation in the Revised Statute of 1868 without change, except that the words County Judge were substituted for the words Probate Judge. The compiler of the General Laws evidently overlooked the amendment of 1870, repealing the Hardscrabble proviso.

In the compilation known as the General Statutes of 1883, this important section of early Colorado law is printed with the amendment made in 1870, as Section 1714 thereof. It reads as follows:

> "In case the volume of water in said stream or river shall not be sufficient to supply the continual wants of the entire county through which it passes, then the County Judge of the county shall appoint three commissioners as hereinafter provided, whose duty it shall be to apportion in a just and equitable proportion, a certain amount of water upon certain or alternate weekly days to different localities, as they may in their judgment, think best for the interest of all parties concerned, and with a due regard to the legal rights of all."

The same section was again printed in 1890 as Section 2259. of Mills Annotated Statutes.

Just how far any part of this old statute can be considered as now in force, may be a somewhat open question. Certainly the act of 1879, providing for the appointment of one water commissioner for each water district, constitutes an implied repeal of the power of the County Judge to appoint three commissioners; but whether the courts will or will not hold that the power "to apportion in a just and equitable proportion, a certain amount of water upon certain or alternate weekly days to different localities, as the commissioner may in his judgment think best for the interests of all parties concerned, and with a due regard to the legal rights of all," still vests in the water commissioner of the district, may be fairly debatable.

Further on we will consider this subject of apportioning water in time to different localities under the discretionary powers of the water commissioner, without reference to this statute. From any point of view, it is interesting to note that there has been legislative recognition of the wisdom of such alternate supply under certain circumstances of scarcity.

Prior to the year 1879, the system of dividing the water of running streams among the different ditches entitled thereto, was extremely crude. There had been no provision made to determine judicially or otherwise, except in the discretion of the commissioners, to how much water each ditch was entitled.

### LEGISLATION NOW IN FORCE.

In 1879 the present Colorado system of adjudicating priorities and providing for the enforcement thereof, had its inception. It was attempted in that year, by the second general assembly, to provide a system of procedure to adjudicate priorities, but that part of the act of 1879 was found defective, and amended in 1881. In the act of 1879 ten irrigation districts were created, and it was provided that others might be created by the Governor, on petition of parties interested. Subsequent legislation has created new districts so there are now 69. The sixteenth section of the act provided for the appointment of one commissioner for each district, and the method of his appointment.

## WATER COMMISSIONERS.

### POWERS AND DUTIES UNDER THE STATUTES.

The 18th section of the act of 1879 (Section 2384 of Mills Annotated Statutes) defined the duties of the water commissioner as follows:

> "It shall be the duty of said water commissioner to divide the water in the natural stream or streams of their districts among the several ditches taking water from the same, according to the prior rights of each respectively; in whole or in part to shut and fasten, or cause to be shut and fastened, by order given to any sworn assistant, sheriff or constable of the county in which the head of such ditch is situated, the head gates of any ditch or ditches heading in any of the natural streams of the district, which in a time of scarcity of water, shall not be entitled to water by reason of the priority of the rights of others below them on the same stream."

In 1887, Superintendents of Irrigation were provided for and their duties prescribed. The 5th section of the act (Sec. 2451, M A. S.), reads as follows:

> "Each water commissioner shall report immediately to the superintendent of irrigation of his division, when he is called out, and when he ceases to be needed, and shall, during the continuance of his duties, be under the control of the superintendent of irrigation of his division."

The 8th section of the same act (Sec. 2454, M. A. S.), reads as follows:

> **"Said superintendent of irrigation shall have the right to call out any water commissioner of any water district within his division, at any time he may deem it necessary, and he shall have the power to perform the regular duties of water commissioner in all the districts within his division."**

In the 9th section of the same act (Sec. 2455, M. A. S.), each water commissioner is required to make reports to the superintendent of irrigation as often as required by him. Such reports of a water commissioner must contain information concerning,

> **(a) The amount of water needed to supply all ditches and reservoirs in his district, meaning of course, under each stream in the district.**
>
> **(b) The amount of water coming into the district to supply such needs.**
>
> **(c) Whether the water supply is on the increase or decrease.**
>
> **(d) What ditches or reservoirs are, at the time of the report, inadequately supplied.**
>
> **(e) The probability concerning the supply prior to the next report.**
>
> **(f) Such other and further information as the superintendent of irrigation of that division may suggest.**

Printed blank forms prepared by Superintendent of Irrigation would be helpful in the matter of such reports.

The 10th section of the same act of 1887 (Sec. 2456, M. A. S.) pertains in part to the duties of the water commissioners. It provides, in substance, that when any ditch or reservoir is not receiving its regular water supply, its owner may report such fact to the water commissioner of his district, who shall, if practicable, apportion the water in his district to aid the ditch mentioned, if he can do so, and shall, if necessary, by telegram report the situation to the superintendent of irrigation, to enable that official, if necessary and practicable, to supply the needed water at the expense of junior appropriators from some other district.

In 1889 an act was passed, the first section of which (Sec. 2293, M. A. S.) requires any person or corporation diverting water from a public stream, to erect and maintain headgates and waste gates in connection with his ditch, and provides that after five days' notice so to do by the water commissioner of the district or by the state engineer, if such headgates are not erected, then the same shall be constructed by the water commisisoner, who is also vested with power to recover the expense thereof from the delinquent ditch owner.

The second section of the same act (Sec. 2294, M. A. S.) contains similar provisions, with reference to the keeping of suitable locks and fastenings on headgates where water is taken from a public stream, and on failure of the owner so to do, it is made the duty of the water commissioner to provide suitable locks and fastenings, and collect the cost thereof from the ditch owner.

By another act adopted in 1889, many important new duties and powers were thrown upon water commissioners. By its first section (Sec. 2386, M. A. S.), a water commissioner in discharging his duties is vested with the power of a constable, and is authorized to arrest any person violating his orders relative to the opening or shutting down of headgates, or the using of water for irrigation purposes, and to cause the offender to be prosecuted before a Justice of the Peace.

In a proviso to the same section, the orders of the superintendent of irrigation and of the state engineer shall be treated as superior to those of the water commissioner.

By the 3rd section of the same act (Sec. 2388, M. A. S.), the water commissioner is given power to employ a suitable assistant or assistants to aid him in discharging his duties. Such assistants are to take the same oath as the water commissioner, and to obey his instructions.

The 5th section of the same act (2391, M. A. S.), being a very important one, is here quoted in full, as follows:

> **"It is hereby made the duty of the water commissioner, after being called upon to distribute water, to devote his entire time to the discharge of his duties when such duties are required, so long as the necessity of irrigation in his district shall require; and it is made his duty to be actively employed on the line of the stream or streams in his water district, supervising and directing the putting in of headgates, waste-gates, keeping the stream clear of unnecessary dams or other obstructions, and such other duties as pertain to a guard of the public streams in his water district; and for willful neglect of his duty he shall be liable to fifty dollars fine, with costs of suit."**

The 6th section of the same act (Sec. 2392, M. A. S.) provides that the water commissioner shall not begin his work until called on by two or more owners or managers or persons controlling ditches in his district, by written application, stating necessity for their action; it is also provided that the water commissioner shall cease to perform his duties when the necessity therefor shall cease.

In the same year, 1889, another act was passed imposing a penalty for the bribing of persons in charge of the distribution of water. This section (Sec. 2398, M. A. S.) makes it a misdemeanor for any water commissioner or his assistant to take or receive any money, promises or favors, or anything of value intended to influence him dishonestly to favor any person in the distribution of water to the injury of others.

In 1895 another statute was passed providing for the regulation of the use of the waters of the state. The same, consisting of three sections, is printed in the third, or supplemental volume of M. A. S., as sections 2384a, 2388a, and 2384b.

By the 1st section of the act (Sec. 2384a, Mills' Sup.), each water commissioner is empowered, and it is made his duty on application of the owners of one or more ditches in his district, immediately to make or cause to be made, a thorough examination of all ditches within his district, to ascertain what use is being made by the consumers thereunder. If he ascertains that any ditch owner is permitting any water flowing in his ditch to be wasted, or to be wastefully, extravagantly or wrongfully used by its consumers, or put to any other use than that to which it is entitled to be used in its priority order, when needed by others, it is made the duty of the water commissioner immediately to shut off the supply of water in such ditch, to such an extent as in his judgment water was wasted, or wastefully, extravagantly or wrongfully used.

The 2nd section of the act (Sec. 2388a, Mills' Sup.) authorizes the water commissioner to appoint not to exceed two deputies to speedily make the examination provided for in section 1, just mentioned.

The 3rd section of the act (Sec. 2384b, Mills' Sup.) makes it a misdemeanor for any water commissioner to fail to perform the duties mentioned.

This act is one of special importance, increasing both the powers and duties of the water commissioners, and if properly executed will be of great benefit.

In 1897 an act was passed to regulate the exchange of water between reservoirs and ditches and the public streams, whereby, among other things, it was made the duty of any person or company transferring water from one public stream to another, to construct and maintain under the direction of the state engineer, measuring flumes or weirs, and self-registering devices, where the water leaves its natural watershed, and is turned into another, and also where it is finally diverted for use from the public stream.

The 3rd section makes it the duty of the water commissioner of the district where the water is used, to keep a record of the water so turned into his district from another.

The 4th section contains similar provisions as to delivering water to a public stream from a reservoir, so that the owner of the reservoir may take an equivalent amount higher up the stream in exchange. The section requires the water commissioner to determine and regulate this matter of exchange.

In 1899, by an act in relation to irrigation, a system of procedure in court is provided, in case a permanent change of the point of diversion of an appropriation is desired, to enable the court to determine whether the proposed change will be injurious to juniors or not. When a decree is entered in such a cause, a certified copy thereof is to be delivered to the state engineer, and that official thereupon issues a notice to the water commissioner of the district affected, notifying him of the change made. Thereupon the water commissioner is required to allot the priority right to the new ditch, in pursuance of the new decree.

The 3rd section of the same act, permitting between ditch owners an exchange of water for a limited time to save crops, or to use the water more economically, provides for the owners making such loan or exchange, to give notice concerning the same, and thereupon requires the water commissioner to recognize the exchange in distributing the water.

No legislation of the Thirteenth General Assembly which has recently adjourned, affecting the duties of water commissioners has been brought to our attention.

## COMMENTS ON POWERS AND DUTIES OF WATER COMMISSIONERS.

The foregoing compilation of legislative enactments defining the powers and duties of water commissioners makes it plain that the office is one of great responsibility and importance, requiring for the efficient discharge of its duties, to carry out both the letter and the spirit of the statute, constant attention, strict impartiality, energy, tact, hard work, and ability. From the very nature of the duties imposed, the fluctuations in supply of water during an irrigating season, the need of its use frequently being greater than the supply, considerable discretion must be exercised by the official in charge. It may be said at the outset that it is probably not possible, with the necessary limitations of human wisdom, for any water commissioner to attain perfection in performing these duties. But every faithful official should aim to attain as near an approach as possible to a perfect discharge of all the duties imposed upon him.

It is to be hoped that in the course of time, and with increased experience, the service will be improved; that mistakes and neglect of commissioners in the past and the injuries resulting therefrom, will occasion greater diligence and care, and more freedom from error in the future; that in time, the sooner the better, the selection of these officials will be removed more and more from the scrambles of politicians, so that a trained class of officials to perform these important duties necessary for the proper development of one of the leading industries of the state, will be evolved. In time, the demands of the irrigators of the state will be such that a faithful, conscientious and experienced official will be retained in office irrespective of the fluctuations in political control of the state government.

An effort will now be made to make some suggestions concerning the proper discharge of many of the duties of water commissioners prescribed by the statutes.

The principal duty of a water commissioner is that defined in the first statute whereby the office was created, tersely expressed in Sec. 2384, M. A. S.

> **"To divide the water in the natural stream or streams of his district, among the several ditches taking water from the same, according to the prior rights of each respectively."**

The language following the above in the statute, conferring power to shut down and fasten the headgate of any ditch not entitled to water is a mere incident to the language quoted.

The duty now under consideration involves consideration of the decrees whereby priorities have been judicially determined. Those decrees fix relative priorities of the several ditches in the stream in whose behalf evidence was introduced, the dates of such priorities, and the maximum amount of water under each priority to which the several ditches were then entitled. They do not provide that the maximum amount so defined under each priority shall be permitted to run into the ditch named at all times, irrespective of the necessities of consumers under the ditch. In most of the districts, perhaps in all, the decree defining priorities was made subject to several conditions, among which perhaps the most important was that which in substance stated that the decree should not be construed as adjudging to any claimant the right to take and carry by means of any ditch or reservoir, any water except to be applied to the use for which the appropriation was made, nor to allow any excessive use or waste of water whatever, nor to allow any diversion of water except for lawful and beneficial uses.

It is not the intention of the statute or of the decrees that the water commissioner, who is the executive officer to see that the decree and its provisions are enforced and observed, shall be permitted to ignore the limitations and conditions stated in the decree, and to deliver the maximum amount constantly throughout the irrigating season to a senior appropriator, or to deliver the maximum amount at any time when it is not actually needed for the necessary and beneficial irrigation of crops. In considering this general power and duty it is necessary also to discuss later statutes enacted for the purpose of emphasizing the importance of certain duties incident to the general power, and necessary to render the same effective. First among such provisions is the fifth section of the act of 1889 making it the duty of the water commissioner to devote his entire time to the discharge of his duties when necessary, and specially to be actively employed on the line of the stream to supervise the water delivery; to keep the same clear of unnecessary dams and obstructions, and to act as a guard of the stream. This requirement of the statute demands the most constant vigilance. Many grave wrongs have been permitted on account of the failure of water commissioners to discharge this important duty. The writer's attention was called within the last two or three years to the fact that on one of the streams of the state for several years persons having ditches of quite late construction and without judicial decrees, had been taking water from sloughs and tributaries of the river, to the injury of early decreed appropriators on the stream, without any interference or action of the water commissioner to prevent such abuse.

It is manifestly the intention of the law that the water commissioner should act as faithful servant of all the appropriators on the stream, to see that their rights are protected under the judicial decrees. The administration of the water system of the state was provided by the legislature so that there should be some one person to act as agent for all, to see that their rights were respected, so as to obviate the necessity of farmers, busy with their agricultural work, employing a man to patrol the stream and to discover whether or not they were defrauded of their property rights. It is to be feared that there are too many water commissioners who are neglectful of the emphatic language of the statute requiring them to be constantly watchful. Too many commissioners wait to have complaint made to them of unlawful diversions, without themselves taking the initiative in such matters. It is evidently not the purpose of the statute that a water commissioner shall draw a fairly liberal per diem merely for giving orders concerning a few of the main ditches in his district, and waiting for some one to complain that a wrongful diversion is being made by a late ditch from some slough or tributary, or from the main stream itself, but that he should be actively concerned and have his assistants under his immediate supervision active to watch for abuses, and to prevent them, if necessary by the full force of the county.

It would seem that the statute mentioned was passed in 1889 to enforce greater vigilance on the part of the water commissioners. Three sections (Secs. 2386, 2388 and 2391, M. A. S.) were enacted for this purpose. The vesting a water commissioner with the power of a constable, and imposing upon him the duty of prosecuting for violation of his orders, and particularly the fifth section (2391 M. A. S.), making it his duty to be actively employed, supervising and directing putting in headgates, waste gates, etc., and acting as a guard of the public stream, and especially making it a misdemeanor subject to $50 fine to willfully neglect this duty, indicates the legislature was led to believe that the previous general definition of his duty to divide the water according to the prior rights of all, was not found in practice sufficiently definite to bring forth the activity needed. Everybody knows that the imposing of a penalty to follow a successful prosecution for neglect of duty, is not of itself very effective in many matters, because of the reluctance of citizens to institute such prosecutions, and of the difficulty of obtaining convictions. But the passage of such a statute should have great influence on faithful officials in calling their attention to what is expected of them under their oaths of office. It is sometimes unfortunately true that persons in public service are less disposed to make active and constant exertion than are those in the employ of private persons or companies. It is respectfully urged that the water commissioners of this state should each and all resolve not to fall into such careless habits, but to remember what is expected and demanded of them by the plain language of the law and by their official oaths.

Another duty specially imposed by statute in 1895, which is really only ancillary to the duty of apportioning the waters of the stream according to the prior rights of all, is that defined in Sec. 2384a, Mills' Supplement. The water commissioner is required, on application of the owners of any one or more ditches in his district, at once, thoroughly to examine the ditches under his supervision to ascertain what use of water is being made by consumers. Then if he ascertains the water under any ditch is being wasted, or is wastefully, or extravagantly or wrongfully used to the injury of other appropriators, he must shut off the water supply of such ditch to such extent as in his judgment the water was so wasted or otherwise wastefully or wrongfully used. As the greater includes the less, it is believed that if a ditch owner asks a water commissioner to make an investigation of some particular ditch and not of all of the ditches in his district, he should do so either in person or by a deputy. It will be noted that the third section of the same act of 1895 (Sec. 2384b, Mills' Supp.) makes it a misdemeanor for any water commissioner to fail to perform this duty. It may be further observed that it is certainly not improper, and in many instances it may be the duty of a conscientious official if his attention is in any way called, without formal complaint of a ditch owner, to the fact that water is being wrongfully and wastefully used under some particular ditch in his district, to make the investigation on his own initiative and prevent the abuse if he find it is taking place. It is further suggested that in any event when a water commissioner has reason to believe that any ditch with an early priority is demanding more water at a particular time than it really needs, or for the purpose of using some water for an improper purpose to the injury of some junior appropriator, he can keep fully within the law by advising the superintendent of irrigation of his belief that investigation of such ditch is necessary, whereupon that official can give him special instruction to make the investigation.

While the power and duty now being considered is specially enjoined by statute and should, whenever necessary, be faithfully and fearlessly performed, it cannot be overlooked, that the power is one of a very delicate nature since it reposes very much discretion in the water commissioner, sometimes likely to be abused and even with the greatest care liable to result in litigation. Each water commissioner should endeavor practically to accomplish the end desired by adopting such a course, at least in the first instance, as will prevent the waste or extravagance complained of or suspected, through the pressure of persuasion and advice before resorting to more arbitrary and extreme measures. To illustrate: If a water commissioner has good reason to believe under some ditch in his district having a large early priority, when water is demanded up to the maximum amount called for by a decree, that with such delivery of water, a good deal is wasted, that the roads under such ditch are flooded, and other like indications of wasteful use are brought to his attention, it may be the part of wisdom for him, first to approach the superintendent or owner of such a ditch, and inform him of his reason to believe that the ditch should get along with considerable less water without anybody being injured, call his attention to the power and duty thrown upon the water commissioner under the statute, and request the superintendent or ditch owner for a few days to see how he can get along with a more limited supply. It is believed in many cases extravagant use of water, particularly that due to carelessness can be prevented, and the rights of junior appropriators in this way be protected without the water commissioner being compelled to go to considerable expense to adopt more rigid and arbitrary methods. However, in all cases when the commissioner finds it necessary, he should vigorously use all the powers given him by the statute to prevent such wasteful use of water.

Under the general power of distributing water with due regard to the prior rights of all, another general topic should be treated. So far as it is possible so to do, it should be the aim of the water commissioner to use the influence of his office to bring about the largest possible production of crops under all the ditches in his district. When he finds that crops are becoming parched and withered under some ditch he can properly seek to persuade owners of ditches having senior appropriations, who are not in very urgent need of water at the time, to make some concessions for the benefit of those in greater need.

In this connection, attention is again called to the early legislation of Colorado Territory, whereby commissioners appointed by the County Judge were required to apportion water of the stream on alternate days to different localities as they may in their judgment think best for the interests of all parties concerned, and with due regard to the legal rights of all. Experience has shown in distributing water under the larger ditches with numerous consumers, at a time when the supply is limited, much better results are accomplished by delivering the entire available supply alternately, to a fraction of the consumers for one or two days, to other consumers, and so on, because with a better head of water better results can be obtained in a short time than with a small head in a much longer time. The same principle if permitted by law could probably be applied successfully in distributing water among different ditches when the supply in the stream becomes limited. It is, of course, a subject of grave doubt as to whether a water commissioner can alternate the supply in the manner suggested against the consent of the ditch owners affected thereby. But it is suggested, that such consent may be obtained in some instances through the exercise of tactful suggestions by the water commissioner upon the understanding that some benefit will result to the party making the concession, by means of a return concession in his favor later on.

To illustrate: We will suppose that there are two ditches each having a capacity of carrying 100 cubic feet per second, and that there are no other ditches to interfere with the arrangement; that ditch A has priority numbers 1 and 3 each for 50 cubic feet per second; that ditch B has priorities numbers 2 and 4, each for 50 cubic feet per second, and that the river at the particular time under consideration supplies only 100 cubic feet per second for the two ditches, we will say for a period of two weeks. It is evident under the circumstances stated that a strict compliance with the prior rights of the two ditches will give each of them 50 cubic feet per second during the time mentioned. Consumers under both ditches under those circumstances would derive benefit by authorizing the water commissioner to deliver 100 cubic feet per second to ditch A for half the time, and 100 cubic feet to ditch B for the remaining half of the time or on alternate days. It will be noticed that under this hypothetical case each ditch will get just as much water as under the other plan, but the probabilities are that the same amount of water will do very much more good if given in double the quantities for half the time.

The last section of the statute of 1899 confirming temporary loans or exchanges of water, was evidently adopted to apply to just such a case where two ditch companies themselves get together to make such an agreement and notify the water commissioner thereof. But it is here suggested that a water commissioner would be enabled in many instances to accomplish a great deal of good by himself taking the initiative and urging the owners of different ditches to enter into such an arrangement at times of scarcity. He is familiar with conditions in the whole district, and can see what ditches can be best helped by such an arrangement with justice to all.

Human nature is such that men can be induced to do things by good tact and by persuasion of an official in charge, to which they will not submit under arbitrary exercise of power. It is perhaps unnecessary to state, to enable a water commissioner to accomplish the best results in the exercise of discretion and the use of persuasion, he must have the confidence of the ditch owners of his district as an official who is wholly disinterested and impartial, who is not seeking to aid any particular ditch to the disadvantage of another, but who is conscientiously striving to attain the best result for all the ditches in his district. To attain this confidence, he should have no favorites or pets, he should always show his readiness to respect the rights of senior appropriators; he should be vigilant in protecting the stream and all its sloughs and tributaries from invasions of persons who are wrongfully taking water therefrom. When owners of ditches with early appropriations have full confidence in a water commissioner, when they know that he has supplied them and is ever ready to supply when they really need it with all the water to which they are entitled, they will be much more ready at times when they are not in such urgent need to forego some of their claimed rights at his suggestion for the benefit of others whose crops are suffering. Under such circumstances the senior appropriators will readily acquiesce in suggestions made by water commissioners, believing that they will obtain a full equivalent for any concession they may temporarily make.

Another power or duty required of water commissioners worthy of some comment, is that mentioned in the fifth and ninth sections of the act of 1887 (Secs. 2451, 2455, M. A. S.) The last named sections call for reports to be made by the water commissioners to the superintendent of irrigation as often as required by him. It is to be observed that these reports are to contain not only the special matters mentioned in the statute, but also further information when called for or suggested by the superintendent of irrigation. A water commissioner has more direct and immediate knowledge of the conditions in his own district than does the superintendent of irrigation. Without abusing his power and in full compliance with the spirit of the statute, it is proper and desirable that water commissioners shall make frequent reports, and as the result of their experience make frequent suggestions to the superintendent of irrigation so that that official can study the whole problem in his whole division and make suggestions to other water commissioners helpful to bring about the best results of husbandry.

## SUPERINTENDENTS OF IRRIGATION.

### POWERS AND DUTIES UNDER THE STATUTES.

As we have already seen, the division of the irrigated area of the state into water districts, each managed by a water commissioner, had its inception in the legislation of the year 1879. The creation of larger divisions, known as water divisions, was made in the year 1881 under an act to provide for the appointment of a state engineer, etc. Four water divisions were created in 1881, and two more in 1889. One was created by proclamation of the Governor in 1901. There are therefore now seven water divisions.

The office of superintendent of irrigation having general supervision over each division was not established until the act of April 4, 1887. The first section of that act (Sec. 2447, M. A. S.) provides for the appointment of superintendents of irrigation for each water division, with proviso that the Governor shall not appoint such official for any division until the Board of County Commissioners of some county included therein shall have adopted a resolution requesting such appointment.

The duties of superintendent are defined in the act. The second section (Sec. 2448, M. A. S.) was as follows:

> **"Said superintendent of irrigation shall have general control over the water commissioners of the several districts within his division. He shall, under the general supervision of the state engineer, execute the laws of the state relative to the distribution of water in accordance with the rights of priority of appropriation, as established by judicial decrees, and perform such other functions as may be assigned to him by the state engineer."**

The third section (Sec. 2449, M. A. S.) provides that the superintendent of irrigation shall be governed by the statutes, and to better discharge his duties he is authorized to make other regulations to secure equal and fair distribution of water in his division in accordance with the rights of priority of appropriation, which regulations adopted by the superintendent shall be merely supplemental to and in aid of the general statutory provisions.

The fourth section (Sec. 2450, M. A. S.) gives the right of appeal to the state engineer from any order or regulation from the superintendent of irrigation.

The fifth section (2451, M. A. S.) requires the superintendent of irrigation to commence the discharge of his duties when the first water commissioner in his district is called out, and to continue to perform the same until the last commissioner therein ceases to be needed. It also provides for reports from water commissioners to the superintendent as heretofore noted.

The seventh section (Sec. 2453, M. A. S.) requires each superintendent of irrigation within thirty days after his appointment, to send to the Clerk of the District Court in all counties in his division having jurisdiction over the adjudication of priorities, a notification of his appointment, and requesting a certified copy of every decree of the District Court establishing priorities of appropriations of water used for irrigation purposes. It is made the duty of such clerk to transmit such certified copy to the superintendents of irrigation, and that official is then required to cause to be prepared a register of priorities of appropriation of water for his division, based upon such decrees. He is then required to prepare a list of all the ditches, canals and reservoirs within his division, arranging the same in consecutive order according to the dates of appropriations in the whole division, and without regard to their number in each water district alone. He is also required to make a tabulated statement of all ditches, canals and reservoirs in his division, to whom such priorities have been decreed, containing in separate columns,

(a) The name of the ditch, canal or reservoir.
(b) Its number in the division.
(c) The district in which it is situated.
(d) Its number in its proper district.
(e) The number of cubic feet per second to which it is entitled under each priority.
(f) Such other and further information as he may deem useful.

The 8th section (Sec. 2454, M. A. S.) gives the superintendent of irrigation power to call out any water commissioner in his division at any time he may deem it necessary; also power to perform the regular duties of the water commissioner in all districts in his division.

The 9th section of the act of 1887 (Sec. 2455, M. A. S.) provides that all water commissioners in the division shall report to the superintendent of irrigation. The contents of said report have heretofore been referred to in discussing the powers and duties of water commissioners. In addition to the matters detailed in the statute, the superintendent of irrigation is authorized to call for such other and further information as he may suggest. Said official is required to file such reports, to ascertain how water is being distributed, and if as the result of the division into districts, ditches are deprived of water to which they are entitled in the division as a whole by some junior ditch in one district receiving water when a senior ditch in another district which can be supplied with the same water is not receiving its proper supply, then it is the duty of the superintendent to at once order the post-dated ditch, canal or reservoir to be deprived of supply so that the water will run down to the older ditch in the other district. This section specially enjoins upon the superintendent of irrigation to make orders to enforce the priorities of appropriation according to his tabulated statement of priorities for the whole division, without reference to the district lines. The reports of water commissioners to the superintendent are required to be filed in the office of the state engineer.

In the 10th section (Sec. 2456, M. A. S.) it is provided that when the owner of any ditch, canal or reservoir in any district within the division fails to receive the regular supply of water to which he is entitled, its owner or manager may report the same to the water commissioner, and that official, if he finds it necessary, shall report by wire to the superintendent of irrigation, and said last named official shall thereupon, if he finds he can give such ditch, canal or reservoir a supply at the expense of a latter priority in another district, to enter orders accordingly.

In 1901 there was passed an act in relation to irrigation, found in Session Laws of 1901, pages 193 to 196.

Under the 1st section (p. 193), when the owner of any irrigation structure taking water from any stream fails to erect or maintain in good repair a suitable and proper headgate and measuring flumes or weirs at its point of intake, together with necessary embankments therefor so as to control the water at all ordinary stages, the superintendent of irrigation (or the state engineer), after giving ten days' written notice, is required to refuse to deliver to the owner of such irrigation structure any water until such owner shall erect or repair the headgate and measuring flumes.

The 2nd section (p. 194) pertains to the maintenance of measuring flumes or weirs to determine the amount and volume of water turned into one stream from another, or from a reservoir or ditch into a public stream to be again rediverted. When the owners of a ditch or reservoir so used fail and neglect to erect suitable and proper measuring flumes or weirs for the purpose mentioned, it is made the duty of the superintendent of irrigation (or the state engineer), after five days' written notice, to refuse to allow any water to be taken out from a public stream in exchange for water so turned into the same until the owner shall cause to be erected or repaired such flumes or weirs, both at the point of delivery to the stream and at the point of delivery of taking from the stream.

The 3rd section of the act (p. 194) requires the superintendent of irrigation (or the state engineer) to rate the measuring flume and weir referred to in first and second sections, and to supply the water commissioner of the district where such measuring flumes or weirs are located with a rating table to be used in measuring water.

The 5th section (p. 195) provides that all headgates and measuring weirs used in connection with any irrigation structure to measure and deliver water therefrom and thereto, shall at all times be under the supervision and control of the irrigation officers of the state.

The 6th section (pp. 195-6) pertains principally to the duty of the owner of a reservoir situated upon or in the bed of any natural stream, to cause a survey to be made of the reservoir with contour lines for every vertical foot in depth, to be properly rated by the state engineer. In case of the owner failing to do what is required, the superintendent of irrigation (or the state engineer) is directed to refuse to permit the use of such reservoir.

### COMMENTS ON THE POWERS AND DUTIES OF SUPERINTENDENTS OF IRRIGATION.

Evidently this office was created to relieve the state engineer of duties which otherwise might have been too onerous. It was deemed proper by the legislative department of the government to have a special officer in general charge of all the water commissioners in a single division. The duties of a superintendent of irrigation plainly arrange themselves into two classes. First, the duty to protect senior priorities irrespective of district limits; second, to exercise general supervisory control over all water commissioners in their ordinary discharge of duties. We will discuss these two powers separately.

1st. The power to enforce senior priorities from a main stream as against junior priorities from a tributary of such stream in a different water district, is absolutely necessary to carry out the doctrine of priority of appropriation, since the water of a main stream is practically the result of accretions from its tributaries. Before the enactment of the statute of 1887, there was no proper machinery through the regular water officials to enforce this requirement of the law. Even after the enactment of the statute, little was done until the matter received consideration by the Supreme Court in 1896. It is true that prior to that time, in the case of Strickler vs. Colorado Springs, 16 Colo. 61, reported in 1891, the Supreme Court had declared that any different doctrine would wipe out the principle of priorities upon which our whole system is based. As said by Judge Hayt in that case, "To say now that an appropriator from the main stream is subject to subsequent appropriation from its tributaries would be the overthrow of the entire doctrine."

Still it was not until the decision of the Supreme Court in the case of The Farmers Independent Ditch Company vs. The Agricultural Ditch Company, 22 Colo. 513, handed down May 18, 1896, that the legislation of 1887 had judicial construction. In that case the court, by Chief Justice Hayt, used the following language:

> **"The legislature, by the act of 1887, has attempted to solve the difficulty by providing an officer and making it his duty to distribute water according to the decrees rendered, without reference to the water district in which such decrees are to be found. As we have said, the act does not attempt to make such decrees conclusive as between the various districts, but, in effect, it provides that until the courts shall determine otherwise in some appropriate proceeding, the superintendent shall treat the decrees as prima facie correct and distribute water accordingly. We believe this regulation is fairly within the police power of the state, as defined in the case of White v. The High Line C. & R. Co., supra, and that it violates no constitutional provision; the effect being only to require the distribution of water in a certain way until such time as the rights of the parties can be definitely ascertained and adjudicated."**

Again, in the case of The Lower Latham Ditch Company vs. The Louden Irrigating Canal Company, decided March 5, 1900, reported in 60 Pac. Rep. 629, it was held that the plaintiff having priorities in water district No. 2 from the South Platte river was entitled to a decree requiring the water officials to protect its priority, in times of scarcity, at the expense of junior priorities, from the Big Thompson river, in water district No. 4.

In view of the foregoing, priority in time giving the better right, the statutes as well as judicial decisions, it must now be regarded as beyond controversy that one of the principal duties of the superintendent of irrigation is, without fear or favor, to issue such orders as will enforce senior rights in one district, when they cannot otherwise be supplied, by cutting down the supply of junior rights in other districts on tributary streams.

In connection with this duty of a superintendent of irrigation some discretion must be exercised in determining to what particular water commissioner orders shall be directed, where there are many tributaries supplying the same main stream, having in view the location of the particular ditch needing relief, and the location of junior ditches from which its needs may be supplied. The prime duty of the superintendent is to furnish water to the senior appropriator in the main stream needing it. It may be that such senior appropriator is needing water at a time when thirty different juniors are enjoying water under several tributaries of the main stream and in several districts. In theory, the latest appropriation should be the first cut down, but if, in fact, that appropriator is forty or fifty miles away, and another junior is within a few miles, relief can best be given by depriving the junior on the nearest tributary. In practice, the latter course usually will be found to be necessary. The superintendent in such cases may be able to supply the needs of the senior appropriator by reducing to some extent a large number of juniors, thereby interfering less violently with the regular distribution of any particular district.

Another matter worthy of special note in this connection which must be considered by the superintendent of irrigation, grows out of natural conditions. The writer was informed that on one occasion older ditches in the vicinity of the town of Sterling, in Logan County, were needing water when junior ditches in Morgan County were fairly well supplied, and that a large amount of water, by order of the superintendent of irrigation, was shut out of the junior ditches and required to run into the South Platte river in the month of July or August, when the heat was very great and there was very little water in the main stream, and it was found that all, or nearly all of the water thus taken from the junior ditches was lost by evaporation and otherwise in the sand beds of the South Platte river. In that particular instance, as reported, it was found practically impossible to supply the senior ditch. In 1901 another t[illegible]s made in the same locality, resulting in large increase [illegible] supply, it is claimed, to ditches near Sterling. It is here sug[illegible] that in all such cases the superintendent of irrigation shou[illegible] hastily jump to conclusions, but should in perfect g[illegible] endeavor to supply the senior appropriator, and not [illegible] from so doing until convinced that natural conditions re[illegible] practically impossible.

2nd. The remaining class of d[illegible] devolving on a superintendent of irrigation pertain to hi[illegible] general control over the water commissioners in his division, [illegible]s duty to execute the laws pertaining to distribution and in so doing to make rules and regulations, to carry on correspondence with all his water commissioners, and, at times, if necessary, actively to discharge the duties of a water commissioner. All suggestions made concerning the duties of water commissioners apply equally to superintendents of irrigation. If the superintendent keeps up a constant and active correspondence with all commissioners in his division and makes frequent suggestions to them concerning the proper discharge of their duties, he can be a great aid in reducing the whole work of his division to a more perfect system. By such correspondence he can learn how thoroughly each commissioner is discharging his duties; if complaints are made to him of inefficiency of service in some district, he can give the water commissioner thereof the benefit of his knowledge as to the more efficient conduct of some other water commissioner in another district. If suggestions by correspondence fail to remedy negligence or inefficient discharge of duty in some particular water district, he can, if he sees fit, himself perform the duties of water commissioner in that district for a short time, and thus by personal example give the water commissioner full knowledge of what is expected of him. The power conferred on superintendents of irrigation to obtain information from water commissioners on any subject pertaining to irrigation in his division as he may suggest, enables a brainy superintendent who desires to use the entire power of his office to improve and perfect the system, to do much in that direction, to become a center from which radiates an energy and an influence which will make himself a potent factor in the perfection of the system, whereby the purpose and intent of the law will be carried out, and the best interests of the state and its agriculture be subserved.

Water commissioners and superintendents of irrigation, in carrying out the orders of the state engineer, and in aiding that official in the discharge of his duties, also will improve the efficiency of the system as a whole.

Incidental to all the other duties of a superintendent of irrigation there should not pass unnoticed his importance as a peacemaker and settler of petty disputes, which may arise in his division and the several districts thereof. Much unnecessary litigation doubtless has been and hereafter will be prevented by superintendents of irrigation on the line here suggested. A visit of that official to a water district in which a commissioner is having serious trouble and disputes with ditch owners has a wholesome influence leading to amicable adjustment of such controversies.

It has sometimes been believed that the office of the superintendent of irrigation was somewhat superfluous. Persons inclined to that view have taken the position that the state engineer, as the general center of authority and supervision of all water districts, would be sufficient. Development of agriculture and irrigation is such, however, and the other duties of the state engineer necessarily take so much of his time and attention that it would be difficult, if not practically impossible for any state engineer, however capable, fully to discharge the duties of all the superintendents of irrigation without being compelled to neglect other important duties of his office.

It is believed by the writer hereof that if the superintendents of irrigation constantly devote themselves to a study of the water distribution in their respective divisions and to the thorough and efficient discharge of all of the duties of their offices, both advisory, administrative, appellate, and corresponding, they can constantly be employed and become important factors in improving the water service of the state.

## THE STATE ENGINEER.

### POWERS AND DUTIES WITH REFERENCE TO IRRIGATION MATTERS.

In 1881 an act was passed providing for the appointment of a state engineer in Colorado and of his assistants, and for the establishment of water divisions. (Sess. Laws 1881, pp. 119 to 122). The first five sections of the act cover the matter of water divisions, and the remaining seven sections had reference to the office of state engineer or "state hydraulic engineer," and his duties. The last seven sections were repealed upon the enactment of a new statute on the subject in the year 1889. The original act (Sec. 6) gave the state engineer supervision over the water commissioners of the different water districts in the state. In section seven the state engineer was required to make careful measurements and calculations of the maximum and minimum flow of water in each natural stream from which irrigation ditches took their supply; also to collect facts and make report as to the system of storage reservoirs, and to keep full records of his work, observations and calculations. The tenth section required the state engineer to prepare and render yearly, and oftener if required, full reports to the Governor. The eleventh section required the state engineer, on request of any interested party, on payment of his expenses, to measure and ascertain the capacity of any ditch, canal or reservoir thereafter constructed or enlarged, and to give an official certificate concerning the same. The twelfth section provided that the owners of any ditch, canal or reservoir having decreed water priorities should construct and maintain, under supervision of the state engineer, measuring weirs to measure in cubic feet per second water at the headgate of such ditch, canal or reservoir, or as near thereto as practicable, and the state engineer was required to arrange in tabular form a computation showing the amount of water that would pass such weir in cubic feet per second at different stages or height of water therein, and to furnish copy thereof to the water commissioner interested.

The act approved March 30, 1889, pertaining to state engineer, repealed the last seven sections of the act of 1881, and in lieu thereof adopted eleven new sections still in force. This change removed all the qualifications formerly required. In the original act "no person shall be appointed as such hydraulic engineer who is not known to have such theoretical knowledge and practical skill and experience as shall fit him for the position."

The 1st section (Sec. 2458, M. A. S.) concerned the appointment and qualifications of the state engineer and other like matters.

The 2nd section (Sec. 2459, M. A. S.) gives the state engineer general specific control over the public waters of the state; requires him to make careful measurements of the flow of the public streams of the state from which water is diverted and to compute the discharge; also to collect data and information pertaining to the location, size, cost and capacity of dams and reservoirs to be constructed, similar data concerning the feasibility and construction of reservoirs on eligible sites on which he may obtain information; also data and information regarding the snowfall in the mountains each season to predict the probable flow of the water in the streams.

The 3rd section (Sec. 2460, M. A. S.) requires the state engineer to approve plans and designs for construction and right of way of all dams or reservoir embankments in the state exceeding ten feet in vertical height.

The 4th section (Sec. 2461, M. A. S.) gives the state engineer general charge over the work of water superintendents and water commissioners, requires him to furnish them with all data and information necessary for the intelligent discharge of their official duties. It also requires the superintendents of irrigation and water commissioners to report to the state engineer at suitable times, and especially to make annual statements on blanks furnished by him of the amount of water diverted from public streams under their control and other statistics which he deems of benefit to the state.

The 5th section (Sec. 2462, M. A. S.) pertains to the duty of the state engineer, on the request of any party interested, on payment of his expenses, to appoint a deputy to compute and measure any canal, dam or reservoir or any construction of like nature.

The 7th section provides for the appointment of deputies by the state engineer, under his control, and for whose official actions he shall be responsible.

The 9th section (Sec. 2466, M. A. S.) enables the state engineer to request the owners of any ditch having decreed priorities to construct and maintain under his supervision measuring weirs at or near the head of such ditch, canal or reservoir. The state engineer is required to compute and arrange in tabular form any statement concerning the amount of water that will flow through such a weir at different stages, and furnish a copy thereof to any superintendent or commissioner having control.

The 10th section (Sec. 2467, M. A. S.) makes a cubic foot per second a unit of measurement of flowing water, and a cubic foot the unit of measurement of volume.

The 11th section (Sec. 2468, M. A. S.) requires the state engineer to prepare a full report of his work bi-ennially and to deliver the same to the Governor to be laid before the general assembly.

We have already noted that the fourth section of the act of April 4, 1887 (Sec. 2450, M. A. S.) gives the right of appeal to the state engineer from any order or regulation made by any superintendent of irrigation.

In 1897 an act was passed to provide for and to regulate the exchange of water between reservoirs and ditches and the public streams. (Sess. Laws of 1897, pp. 176-7.)

The 1st section requires the state engineer to determine what reasonable deduction shall be made for seepage and evaporation when a person or company shall divert water from one public stream into another and then divert it from the latter stream.

The 2nd section requires any person or company so transferring water from one public stream to another to construct and maintain, under the direction of the state engineer, measuring flumes or weirs and self-registering devices where the water leaves its natural watershed and is turned into another, and also where it is diverted for use from the public stream.

In the 3rd section it is made the duty of the water commissioner of the district where the water is used, to keep a record of the water so turned into his district.

The 4th section permits, without injury to others, the owner of a reservoir to deliver storage water either into a ditch or into a public stream to supply early appropriations, and in exchange therefor to take from the public stream higher up an equal amount of water, with deduction for loss, if any, to be determined by the state engineer. The same section requires the person or company desiring such exchange to construct and maintain, under the direction of the state engineer, measuring flumes or weirs and self-registering devices at the point where the water is turned into the stream or ditch, so that the water commissioner may readily determine and secure a just and equitable exchange.

In 1899, an Act in Relation to Irrigation, adopted, had special reference to the matter of changing the point of diversion by an appropriator when it can be made without injury to the prior rights of others, and a judicial consideration in advance of the proposed change. In connection with the procedure, the state engineer is to receive and file a copy of the map and decree permitting the exchange, and thereupon to issue a notice to the water commissioner in charge, notifying him of the change. (Sess. Laws of 1899, p. 236, Sec. 2.)

Also in the year 1899 an act was passed in relation to reservoirs. (Sess. Laws of 1899, pp. 314 to 317.)

The 1st section provides that no reservoir of a capacity of more than 75,000,000 cubic feet, or having a dam or embankment in excess of ten feet in vertical height, and covering more than twenty acres shall thereafter be constructed, unless plans and specifications therefor shall first be approved by the state engineer. The state engineer is required to act as consulting engineer during the construction of such reservoir, with authority to require the work to be done to his satisfaction. A written statement concerning the work of construction and the completion thereof to his satisfaction must be given by the state engineer specifying the dimensions and capacity of the reservoir.

The 2nd section provides for the expenses of the state engineer, and a per diem for his services to be paid by the reservoir owner.

The 3rd section requires the state engineer annually to determine the amount of water which it is safe to impound in the several reservoirs within the state. It is made unlawful for the owner of any reservoir to store therein water in excess of the amount determined by the state enginer to be safe.

The 4th section makes it the duty of the water commissioner to withdraw from any reservoir any water impounded therein in excess of the amount determined by the state engineer to be safe, and to prevent the reservoir to be refilled beyond the limit fixed.

The 5th section makes it the duty of the state engineer, when complaint is made to him by persons so located as to be in danger if the embankment of a reservoir should break, that the reservoir is in an unsafe condition, or being filled so as to render it unsafe, to make an examination of the reservoir and determine the amount of water which can be safely impounded therein. If on such examination he finds the reservoir unsafe, or being filled so as to render it unsafe, he shall cause water to be drawn off to such an extent as to render the same safe and prevent further storage of water beyond what he considers the safety limit.

The section enables the state engineer to use any force necessary to perform the duties previously mentioned. It is also made the duty of a water commissioner in such case, if an attempt should be made to refill the reservoir, to act as provided in the fourth section.

The 7th section provides for compensation to the state engineer for mileage and other expenses incurred in making examination.

The 8th section provides for an appeal to the court from any decision of the state engineer in such matters, but with the proviso that the decision of the state engineer shall control until the case is finally disposed of in the courts.

The 9th section provides for owners of reservoirs being responsible for all damages in case of breakage.

The 10th section provides that any reservoir company which after ten days' written notice has been given, fails to obey the directions of the state engineer with reference to the construction or filling of any reservoir, shall be subject to a fine of fifty dollars for each offense, and each day's continuance after the time of notice has expired shall be considered as a separate offense.

In addition to the duties required of the state engineer on the general subject of irrigation, distribution of water, etc., above referred to, many statutes have been passed requiring that official be a member of divers boards of control of sundry internal improvements, to perform important services about state canals, with reference to desert land entries, and many other similar matters not pertinent to this paper except as showing how much of the time of the state engineer is necessarily invaded by other duties besides the important ones above indicated.

An act in relation to irrigation, passed in 1901, has been referred to at the close of the statement of powers and duties of superintendents of irrigation. All the powers conferred upon superintendents of irrigation by that act are also conferred upon state engineers. The sixth section of said act of 1901 (pp. 195-6) makes it especially the duty of the state engineer, on the request of the owner of a reservoir situated upon or in the bed of a natural stream, at the expense of the owners thereof, to cause a complete survey of the contour lines of said reservoir to be made for each vertical foot in depth, and also when he deems it necessary of fractions of a foot; also to prepare a table showing the number of cubic feet capacity of said reservoir for each foot in depth and fractions thereof, and to place a gauge rod in said reservoir, marked in correspondence with the contour lines. In event the owner fails to cause said survey, etc., to be made, it is made the duty of the state engineer to refuse to permit the reservoir to be used until such survey, etc., is made.

## COMMENTS ON POWERS AND DUTIES OF THE STATE ENGINEER.

The mere recapitulation of the functions of the state engineer as the head of the system of irrigation and distribution of the state, his supervisory control of all water commissioners and superintendents of irrigation, his appellate jurisdiction over subordinate officials, his special duties with reference to the measurement of canals and reservoirs, his supervision and control over the construction of reservoirs, his duty to provide for self-registering devices in many instances, is sufficient of itself to make plain the responsibility of his office.

It is plainly within the intent and purpose of the statute that the state engineer must devote considerable time to a thorough study of the whole system of irrigation distribution of the state. In that connection he must become familiar with the work of the several superintendents of irrigation, and satisfy himself that they are properly performing the duties by law of them required. This also applies to the reports of the several water commissioners. As the state engineer is required to be a man of professional ability as an irrigation engineer, his advice and suggestions to superintendents of irrigation and water commissioners should be of special helpfulness. The result of his study should enable him in his reports to make suggestions to the Governor, and thereby indirectly to the legislature on any desirable change in the law from time to time. His office has always been, and ever should be, of special importance in perfecting the efficiency of the official water service of the state.

The state engineer should insist on obedience to the statute law by persons constructing reservoirs, and by those who desire to exchange water between reservoirs and public streams, or to turn water from one public stream into another. Since the water commissioners are under the control of the state engineer, it is believed that it is within his power to direct water commissioners to refuse to recognize the rights of persons to divert water which is turned into a public stream from some other source of supply, unless the statute concerning self-registering devices and other legal requirements are complied with. The purpose of the statute is that exact justice may be done. The person who adds to the amount of water in a running stream by turning water therein from another stream or from a reservoir, should certainly be entitled to again draw the same amount of water from the stream as a just reward for his enterprise and capital invested. But on the other hand, every safeguard against abuse of this privilege, and to prevent the diversion to the injury of regular appropriators from the stream of a greater amount of water than is supplied thereto, after proper allowance is made for incidental losses, should be rigidly enforced.

Special comment should be made with reference to the importance of measuring weirs at the headgates or canals. It is unfortunately true and well known that when many of the decrees concerning priorities were rendered by the courts, sufficient care was not taken to have correct measurements made, whereby any ditches were decreed priorities really in excess of their carrying capacity. When for a large number of years it has been shown by experience, and as the result of careful measurement, that a ditch has not carried and cannot carry the amount provided in the decrees, sufficient data will be collected to prevent the subsequent enlargement of such ditch to enable it for the first time to carry the maximum mentioned in the decree, and thereby injuriously to affect the rights of junior appropriators. Moreover, such measuring weirs are of great value and aid to the water commissioners in distributing and apportioning the water at times of scarcity, and when ditches having several priorities limited to one or more of their earlier ones.

Press Bulletin No. 7. February, 1901.

# The Agricultural Experiment Station

FORT COLLINS, COLORADO.

## THE SEEPAGE MEASUREMENTS OF THE EXPERIMENT STATION.

One of the effects due to irrigation that is noticed in all countries is the seepage water which returns from irrigation and enters the streams. This is so much that streams may be drained dry and, within a short distance, again have an appreciable quantity of water.

At the suggestion of Hon. B. S. LaGrange, President of the State Board of Agriculture, and at that time Water Commissioner of District No. 3, a measurement was made in 1885 of the Poudre River by the State Engineer's office, and two others were made in 1889 and 1890. In 1891 the Experiment Station took up the matter to investigate in detail the amount and the laws of the increase. Such measurements have since been carried on annually on the whole length of streams in the State, from their exit from the mountains to the State line. These include the Cache la Poudre, the South Platte, the Big and Little Thompson, the St. Vrain and Left Hand creeks, Boulder and South Boulder, Clear Creek, Bear Creek, the Arkansas from the mountains above Canon City to the Kansas State line, the Rio Grande from near Creede to the New Mexican line, and the Conejos. Of these, measurements have been made for four years on the Arkansas and for five years on the Rio Grande, and the others for varying times.

It has been the intention to extend these measurements to other parts of the State as soon as time and means permitted. During the past year, 1900, the measurements were begun on the Western Slope, and were made on the Uncompahgre River from Ouray to Delta. These measurements have required passing over every foot of the streams, visiting every headgate and measuring every stream that leaves the river, as well as those which flow into it. This has required the traveling over, in detail, of very nearly one thousand miles of river during the past season, and from six to eight hundred miles for each of the past four years. In all, some five thousand miles, at least, of river measurements have been made.

A report, giving the results of investigations up to that date, was issued in Bulletin 33. This discussed the relation of the seepage to the area irrigated and to the amount of water applied, as well as the rapidity of the flow of the waters under ground, and showed that the value of this source of water supply amounted to several hundreds of thousands of dollars.

This bulletin has been very widely quoted. The more recent measurements have been given in the annual reports of the Experiment Station, and in the report of the State Engineer. Bulletins discussing these measurements, and comparing them, will soon be issued by the Experiment Station.

In addition to these measurements the Experiment Station has also made hundreds of miles of measurements on canals to determine the amount of loss by seepage from canals, the means of preventing the seepage, and the means of protecting lands from such damage. It is studying the character of the water used in irrigation, for years the amount of water used in irrigation, and other phases of the irrigation question.

The Experiment Station has issued nearly seventy bulletins on matters of agricultural interest—Fruit, Injurious Insects, Sugar Beets, Alfalfa, irrigation matters. Those relating to irrigation matters are (the last ones will soon be out):

1. Report of Experiments in Irrigation and Meteorology.
13. On the Measurement and Division of Water.
16. The Artesian Wells of Colorado and Their Relation to Irrigation.
22. A Preliminary Report on the Duty of Water.
27. The Measurement and Division of Water.
33. Seepage or Return Waters from Irrigation.
45. The Loss of Water from Reservoirs by Seepage and Evaporation.
48. Losses from Canals by Filtration or Seepage.
55. Forests and Relation to Snow.
65. Seepage Waters of the Poudre River.
66. Seepage Waters of the Platte River.
67. Seepage Waters of the Big Thompson Valley.
68. Seepage Waters of the Arkansas River.
69. Seepage Waters of the Rio Grande River.

Press Bulletin No. 8. April, 1901.

# The Agricultural Experiment Station

FORT COLLINS, COLORADO.

## POTATO FAILURES.

W. PADDOCK AND F. M. ROLFS.

The Experiment Station has received a number of inquiries from potato growers in various sections of the State in regard to the failure of the potato crop in certain seasons. These failures seem difficult to explain, since there is little blight in evidence, and they occur with experienced growers as well as with beginners, and on soil that would seem to be in a good state of fertility. In some instances the vines are said to have made a luxuriant growth and remained green till late in the season, but when digging time came the tubers were found to be much under size. In other instances a large growth of vines were found to have set an abnormal number of tubers which failed to develop.

At first thought it would seem that some of the elements necessary to the growth of the potato plants were lacking in the soil, and this may be true in some instances, but it will not explain all of the failures. Certain fungi or plant diseases have been found to be abundant on the potatoes in various parts of the State, which may have something to do in producing these conditions. One of these diseases has been known in America as a potato disease* less than a year, though it has undoubtedly been present in our potato field for a long time. In Europe it is considered to be one of the most destructive potato diseases. The fungus does not confine its attacks to potatoes alone, but is found in a great variety of plants, including alfalfa, clover and sugar beets.

The disease attacks the potato plant just below ground, cutting off free communication between foliage and tubers. In extreme cases the plants may be killed, and much of the so-called late blight or early ripening of the vines may be due to this disease.

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* Dugger and Stewart, Bulletin 186, p. 17, N. Y. State Experiment Station, and Bulletin 186, p. 63, N. Y. Cornell Experiment Station.

The fungus lives over winter on the stems and tubers of the potato, and on various other plants. The fungus adheres to the tubers in the form of dark patches which resemble bits of soil, and which vary in size from that of a mere speck to areas a half inch or more in diameter. The fungus does not injure the potatoes directly, but it detracts from the appearance of the tubers when offered for sale. But the important point is, that when infected potatoes are planted the fungus is planted with them, and thus the disease is propagated year after year.

The fact that the fungus attacks the roots of alfalfa complicates the treatment, since alfalfa is commonly used in the rotation of crops. If potatoes free from the disease are planted on land which has been in alfalfa within two years, the chances are that the crop will be affected, providing there has been any of the fungus on the alfalfa plants. The length of the time that the fungus will live in the soil is not known. German authorities state that it will persist for at least three years. Neither has the kind of crop which should be grown on infected land to starve the fungus been definitely determined; however, it is not known to attack our common cereal crops.

It is too early to recommend a line of treatment to overcome the above conditions, since the cause of the trouble is not positively known; but potato growers who have been troubled in this way may find it profitable to take certain sanitary precautions. Such measures consist in planting potatoes on land on which potatoes, beets, alfalfa or clover have not been grown for at least three years, and potatoes that are free from disease should be used for planting. If there is reason to suspect that the seed potatoes are infected with fungi, they may be treated with corrosive sublimate or formaline, as is recommended for potato scab.

## Formulæ for Treating Diseased Seed Potatoes.*

| | |
|---|---|
| Corrosive sublimate | 1 ounce |
| Water | 8 gallons |

Dissolve the corrosive sublimate in one gallon of hot water, then dilute with seven gallons of water. Allow the potatoes to soak one and one half hours. When dry they may be cut and planted, though it has been found to be good practice to treat the potatoes a week or more before planting, since the treatment may retard germination if done just before planting.

Corrosive sublimate is a deadly poison, and it should be used in wooden or earthen vessels, since it corrodes metals.

| | |
|---|---|
| Formaline | 8 ounces |
| Water | 15 gallons |

Soak the potatoes two hours in this solution, preferably but a short time before planting. This solution is somewhat more expensive than the corrosive sublimate treatment, but it has the advantage of being non-poisonous, and it may be used in any kind of vessel.

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* Jones, L. R., and Edson, A. W., Vt. Sta. Bul., 85.

Press Bulletin No. 9. April, 1901.

# The Agricultural Experiment Station

FORT COLLINS, COLORADO.

## SUNSHINE FOR 1900.

L. G. Carpenter.

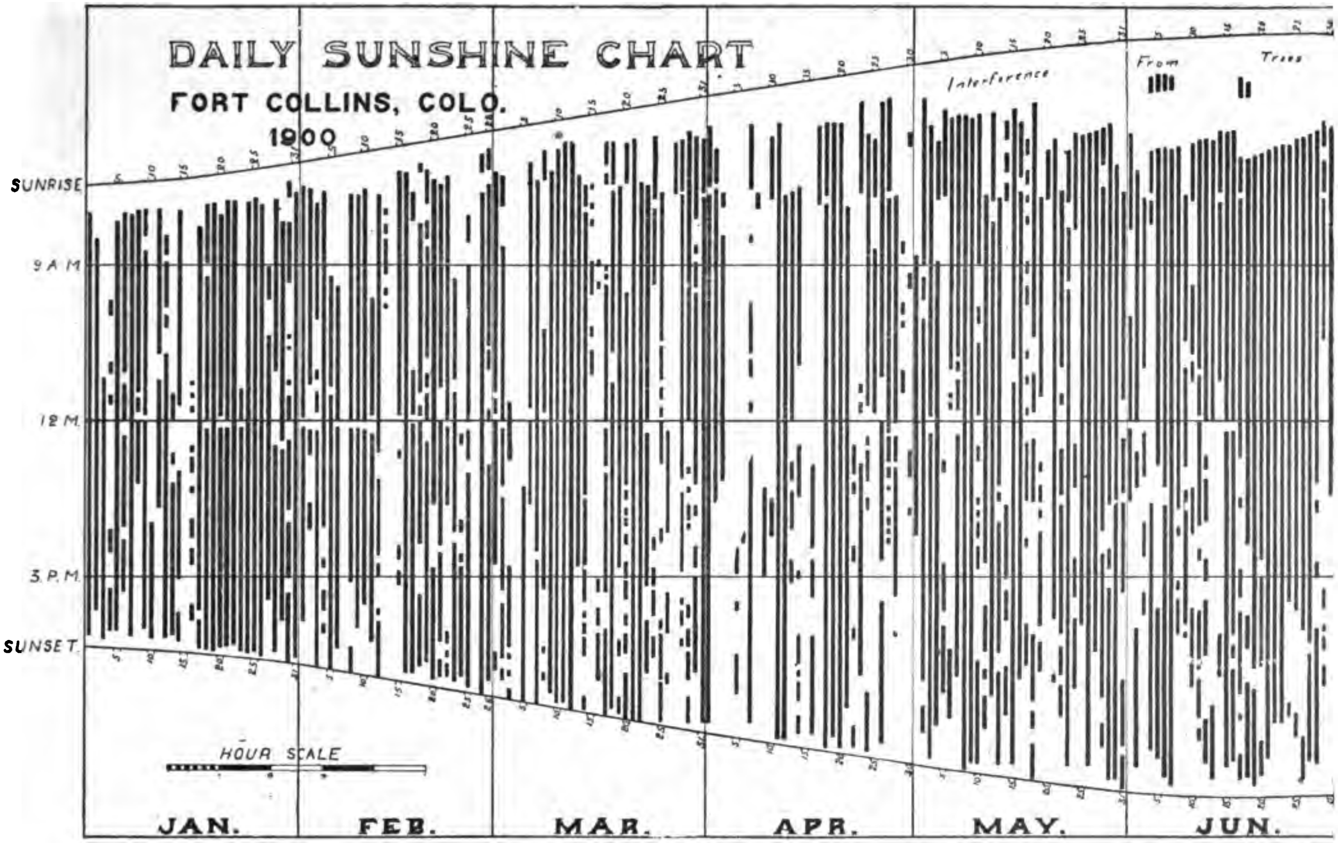
While the pleasure afforded by a sunny day is of common experience, the value of sunshine as an element in the climate, whether from the standpoint of health or spirits or of agriculture, is not often given the importance it deserves. Until recently no attempt has been made to record the amount or intensity, even in those places specially interested in agricultural meteorology.

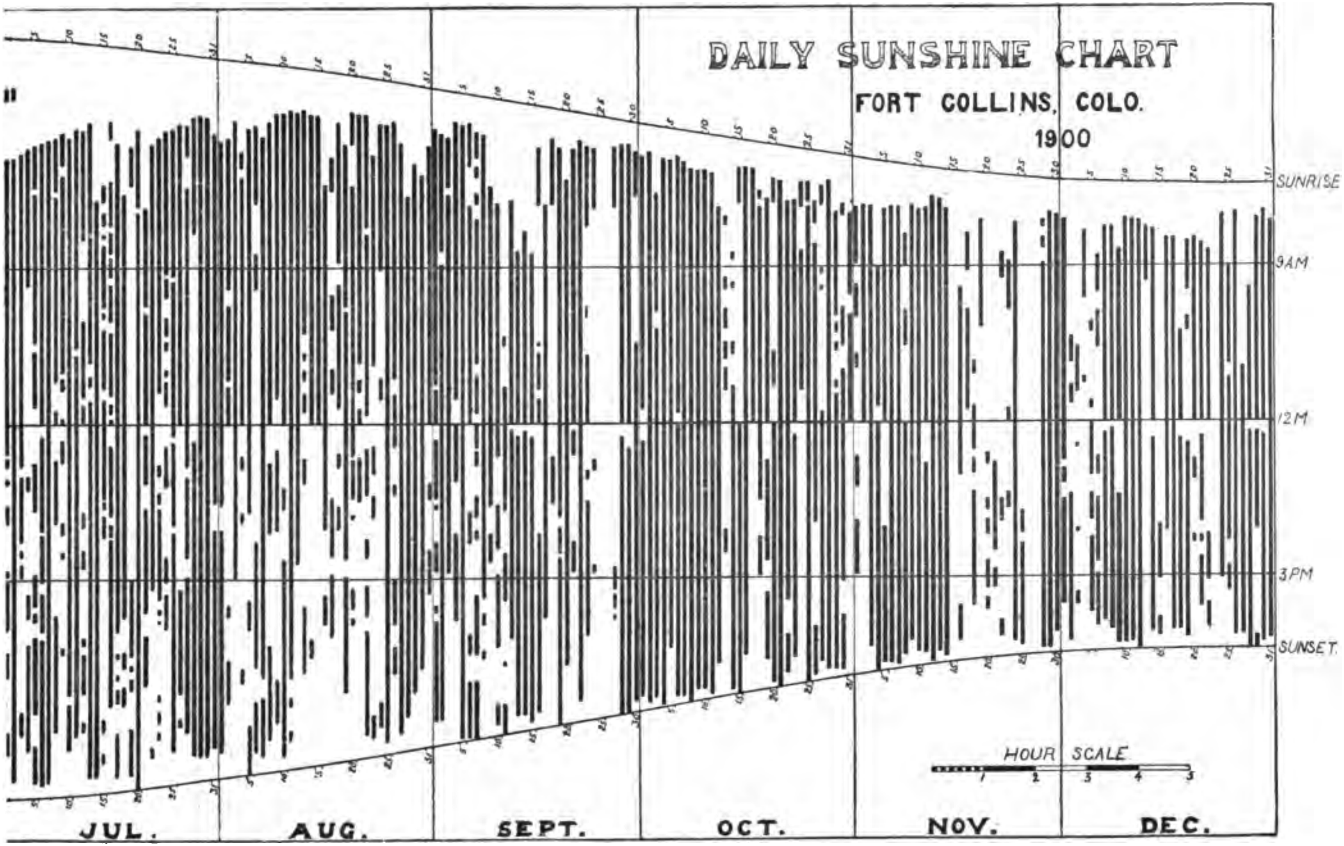
A certain amount of sunlight is recognized as a necessity for plant growth, for without it the development will be absent or unhealthy. With an increase in sunlight, and the presence of direct sunshine, there is almost always a direct improvement in quality, in the amount of essential oils; or in special qualities, as in sweetness, and an increase in the color of fruits and flowers. There is a decrease in the prevalence of certain diseases with direct sunshine. It has been known from time immemorial that dirt and darkness were conditions favorable for disease, while cleanliness and light were unfavorable. Molds and fungi, and the invisible but perhaps more important bacteria, do not thrive in sunshine. Even in diffused light few bacteria develop, and direct sunshine is destructive to most, if not to all, injurious forms within a short time. Sunshine and the drying action of the air are unfavorable to such forms of life, and are Nature's chief disinfectants.

A sunny climate or a sunny home is thus more apt to give the conditions for such physical health as is necessary to permit of sunny dispositions.

The charts show the amount of sunshine at Fort Collins for 1900, as recorded by an automatic photographic recorder and then transferred to the diagram.

A line is given to each day. The black line shows the duration of the sunshine and the hours at which it shone. When broken or absent, clouds are indicated. The longer the break, the longer the duration of the cloudiness. The diagram therefore shows the exact hours at which the sun shown during the year. It is noticeable that the forenoon has more sunshine than the afternoon, and that the winter months had comparatively little cloudiness. The relative amounts vary in different seasons, as a comparison with the charts in Press Bulletin No. 2 of 1900 will show.


DAILY SUNSHINE CHART
FORT COLLINS, COLO.
1900
SUNRISE
9 A.M.
12 M.
3. P.M.
SUNSET.
Interference
From
Trees
HOUR SCALE
JAN.
FEB.
MAR.
APR.
MAY.
JUN.



DAILY SUNSHINE CHART
FORT COLLINS, COLO.
1900

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No. 5. The Russian Thistle as Forage. J. E. Payne.
No. 6. A So-Called Blight Cure. C. H. Potter.
No. 7. The Seepage Measurements by the Experiment Station. L. G. Carpenter.
No. 8. Potato Failures. W. Paddock.
No. 9. Sunshine in 1900. L. G. Carpenter.
No. 10. Sugar Beets: Cultural Conclusions. W. P. Headden.
No. 11. How to Fight the Codling Moth. C. P. Gillette.

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No. 56. The Birds of Colorado. W. W. Cooke.
No. 57. Farm Notes. W. W. Cooke.
No. 58. A Soil Study. Part II. The Crop Grown: SUGAR BEETS. W. P. Headden.
No. 59. Field Notes from Trips in Eastern Colorado. J. E. Payne.
No. 60. Bush Fruits. C. H. Potter.
No. 61. Bromus Inermis. F. L. Watrous, H. H. Griffin and J. E. Payne.
No. 62. Cantaloupes. H. H. Griffin.
No. 63. Sugar Beets. A resume of the work of the Colorado Experiment Station. W. P. Headden.

Meteorology of 1900. Observations; from the Annual Report for 1900. 56 pp. L. G. Carpenter and R. E. Trimble.
Six Years Trials at the Plains Substation; from the Annual Report for 1899. J. E. Payne.

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L. G. CARPENTER, *Director*,
Agricultural Experiment Station,
Fort Collins, Colorado.

Press Bulletin No. 10. April, 1901.

# The Agricultural Experiment Station

FORT COLLINS, COLORADO.

## CONCLUSIONS RELATIVE TO THE CULTURE OF SUGAR BEETS. [*]

By W. P. HEADDEN.

*Soil.* A rich loamy soil is best, but any soil that will produce good crops of grain will grow beets, and even soils too alkali to grow grains will grow beets.

*Preparation of seed bed.* Plow in the fall, subsoiling to fifteen or eighteen inches. Plowing may be done in the spring; in this case it is best to plow immediately before planting. In either case harrow quite smooth and even.

*Subsoiling.* Results at this station show a gain of eighteen per cent in weight of crop due to subsoiling.

*Time of planting.* The time will vary with locality and soil. Early planting gives largest crops. Good results have been obtained with plantings as late as June 13th at this station, and June 15th at Rockyford, but four series of tests of ten experiments each made in different sections of the State show an average excess of 3.4 tons of beets for the plots planted from April 10th to 20th over similar plots planted from May 1st to 10th; 7.3 tons over those planted May 15th to 26th; and 12.4 tons over those planted between May 31st and June 10th.

*Depth of planting.* If the soil is wet, very shallow planting will give good results, but the best results are generally obtained by planting from one inch to an inch and a half.

*Distance between rows.* This should be from 18 to 20 inches if in single rows. Mr. Watrous, in bulletin 21, recommends double rows 12 inches apart and 24 inches between rows. He claims that they are more easily irrigated. Prof. Cooke, in bulletin 57, recommends double rows 11 inches apart and 27 inches between rows.

*Amount of seed.* Good crops have been raised by planting small quantities, three to five pounds of seed to the acre, but it is advisable to sow eighteen to twenty pounds to the

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[*] From Bulletin 63. A Resume of the Publications of the Colorado Agricultural Experiment Station.

The average percentages of sugar for the crops of 1898 and 1899 grown in such a soil were 13.65 and 15.34 respectively; the coefficients of purity were 84.6 and 80.8.

*Relation between size and sugar content.* As a rule medium sized beets are richer than either small or large beets. By medium sized beets is meant such as weigh from one to two pounds. Large beets, weighing from two to four or eight pounds, or even more, may be as rich in sugar and have as high a coefficient of purity as beets of one pound or less, if grown under the same conditions. If not grown under the same conditions they cannot be compared. Even big beets grown under different conditions cannot be compared. Two beets, weighing respectively 2.88 and 2.90 pounds, grown in the same plot of ground within two hundred feet of one another, but under different conditions in regard to water supply, showed 10.45 per cent. sugar, 67.0 per cent. purity, and 16.06 per cent. sugar and 85.1 purity. Big beets *may be* rich beets, the size alone is not determinative.

*Late irrigation.* If the crop has already begun to ripen, either a rainfall or an irrigation which causes a second growth will prove detrimental, but if the crop is in such condition that a second growth is not produced a late irrigation may do good.

*Late over-irrigation.* An excessive late irrigation, one which will even puddle the soil, often does good, hastening the ripening and increasing the sugar. It has not been determined whether it will always produce favorable results. The character of the soil will probably modify the effect.

*The effect of altitude.* The higher Parks of the State are not adapted to this culture, but good crops of rich beets have been grown in the San Luis valley at an altitude of rather more than seventy-five hundred feet.

*Loss in trimming.* The beets growing almost wholly under ground in this State, this loss is reduced to a minimum. Experiments indicate about 13 per cent. loss.

*Amount of sugar in the crown.* There is, on the average, about one per cent. less sugar in the crown than in the beet.

*Cost of growing beets.* This will, of course, vary, but it is not far from thirty dollars per acre, exclusive of ground rent.

**Press Bulletin No. 11. April, 1901.**

**The Agricultural Experiment Station**

**FORT COLLINS, COLORADO.**

# HOW TO FIGHT THE CODLING MOTH.

By C. P. GILLETTE.

Many orchardists spray for the codling moth and still grow very wormy apples. The writer knows of an orchard near the Experiment Station that was sprayed with an arsenical mixture three times last summer and in which fully 80 per cent. of the fruit was wormy at the time of picking in September. Another orchard in the same neighborhood was sprayed twice and had less than 2 per cent. of wormy fruit at picking time. What made the difference? Why is it that one man sprays his orchard and has very little wormy fruit and his neighbor, who also sprays, has nearly all of his apples wormy? This is a question often asked and frequently difficult to answer satisfactorily. That a reason exists for the different results there can be no doubt. The object of this paper is to give the best directions that we can at present for the successful treatment of this insect. Perhaps it will explain to some why they have not met with better success in the past.

## WHEN TO SPRAY.

No date can be fixed upon, yet spraying *must be done at the right time* if the best results are to be obtained. The *right time* is immediately after the blossoms fall and before the calyces of the forming apples close. If there are belated blossoms on the trees after the great mass of bloom has fallen, do not wait for them if some of the calyces are closing. If the trees do not all bloom nearly together, spray the early blooming trees first and then in a few days spray the others. Repeat the application in one week, or, at the latest, ten days.

### HOW TO SPRAY.

Be thorough with the work. It will take more time and material, but if spraying for this insect will pay at all it will pay best to do the work well. Use a nozzle that throws a medium fine spray, not a mist, and direct it so that the liquid will be thrown *into* every blossom or calyx. A misty spray will not carry as well into the blossoms. To make a thorough application, it will be necessary to direct the spray from, at least, two sides of the tree, and if the tree is large, it will be almost necessary to apply from all four sides. In many orchards the trees are so closely set, so large, and poorly pruned, that it is impossible to make a thoroughly good treatment for the destruction of codling moth larvæ.

The one who directs the nozzle for the spraying will find it a great advantage to be elevated as high as the bed of a wagon box at least. If the trees are large, it will be well to use a step-ladder or a dry-goods box in the wagon to elevate him still more.

### NUMBER OF APPLICATIONS.

Orchardists differ widely in opinion as to the number of applications that should be made. Some, noticing that the worms are most abundant late in the summer, think that spraying should be continued throughout the season of growth and report excellent results from spraying five or six or more times. However, it is the opinion of those who have tested the matter most thoroughly at the various experiment stations of the country that it does not pay to spray more than twice, if the two applications are properly made at the best time.

### POISON TO USE.

Here again opinions differ. Probably Paris green is as effectual as any if well applied and if the liquid is kept thoroughly agitated during the spraying. Scheele's green would probably be as effectual as Paris green, is cheaper, and remains in suspension in water better. London purple and arsenate of lime are readily kept in suspension in water but are slower in their action than the above mentioned poisons, and probably less effectual in their death-dealing power. They have the advantage of being very cheap.

Arsenate of lead is kept in suspension without difficulty and is remarkable for its adhesive quality and its entire harmlessness to foliage unless used in great excess. It kills slowly and its value for the destruction of the codling moth has not been very definitely determined.

### PREPARATION OF THE POISONS.

*Paris green, Scheele's green and London purple* may be used in the proportion of 1 pound to 160 gallons of water. It is best to mix the poison in a small amount of water first and then in the full amount for which it was prepared. For each pound of poison used, add to the water one or two pounds of freshly slaked lime. This will lessen the liability of the poison to burn the foliage.

*Arsenate of lime*, by the Kedzie formula is prepared as follows: "Boil two pounds of white arsenic and eight pounds of salsoda for fifteen minutes in two gallons of water. Put into a jug and label 'poison.' When ready to spray, slake two pounds of lime and stir it into 40 gallons of water, adding a pint of mixture from the jug."

If this formula is followed, be sure to use a full measure of fresh lump lime, otherwise some of the arsenic will be left in solution in the water and will kill foliage.

A somewhat simpler method of preparing arsenate of lime is to boil together for three-quarters of an hour 1 pound white arsenic, 2 pounds fresh lime, 1 gallon water. Use one quart of this to an ordinary barrel of water (about 40 gallons).

If a stock solution of this poison is kept, be sure to label it plainly "poison," and it would be well to put in some kind of coloring matter besides.

If arsenate of lead is employed, use not less than one and one-half pounds to 50 gallons of water. Lime need not be added to this preparation.

If more than two applications are made, do not use the poisons in more than two-thirds of the above strengths after the second treatment.

### OTHER REMEDIAL AND PREVENTIVE MEASURES.

*Bandages* of burlap or other cheap fabric placed about the trunks of the trees from the middle of June till September will collect large numbers of the larvæ which gather beneath them for the purpose of changing to the pupa and then to the moth stage. If these bands are removed once in a week or ten days, quite a large percentage of the worms may be collected and destroyed. A bandage four inches wide and having two or three thicknesses of cloth is of good size and may be held in place by means of a single carpet tack thrust through the overlapping ends into the bark of the tree. A band thus held may be quickly taken off and replaced.

*Gathering and destroying fallen fruit*, either by hand or by means of hogs or sheep turned into the orchard, will help some to keep the codling moth in check, but most of the worms leave the apples before they fall. After apples have lain on the ground for three or four days almost no worms can be found in them.

*Protect cellar doors and windows* with screens wherever apples are kept so that moths hatching in the cellar cannot escape to the orchard.

*Clean culture* and the removal of all rubbish in and about the orchard will make it more difficult for the worms to find suitable hiding places for the winter.

*Scraping the loose bark* from trunk and branches will also remove many a safe hiding place for worms during winter.

No one should be discouraged because he does not meet with as complete success in the use of the above remedies as he had hoped the first year. He who persistently and intelligently uses them through a series of years will be almost certain of a degree of success that will convince him of their value.

No. 1. 1901

Special River Bulletin.

The Agricultural Experiment Station

FORT COLLINS, COLORADO.

# Poudre River Bulletin.

### To May 27, 1901.

The river record for the spring by days has been as follows, since April 24.

| DATE. | | 1901. | 1900. | NORMAL. |
|---|---|---|---|---|
| April | 24 | 365 | 1,263 | 367 |
| " | 25 | 434 | 1,223 | 406 |
| " | 26 | 402 | 1,154 | 446 |
| " | 27 | 425 | 1,204 | 541 |
| " | 28 | 399 | 1,807 | 607 |
| " | 29 | 399 | 2,934 | 706 |
| " | 30 | 487 | 2,530 | 651 |
| May | 1 | 619 | 2,551 | 589 |
| " | 2 | 667 | 2,508 | 597 |
| " | 3 | 765 | 2,447 | 611 |
| " | 4 | 685 | 2,251 | 634 |
| " | 5 | 737 | 2,461 | 686 |
| " | 6 | 737 | 2,354 | 729 |
| " | 7 | 744 | 2,447 | 784 |
| " | 8 | 768 | 2,486 | 842 |
| " | 9 | 825 | 2,586 | 916 |
| " | 10 | 999 | 2,777 | 974 |
| " | 11 | 1,091 | 3,012 | 999 |
| " | 12 | 1,205 | 2,992 | 1,024 |
| " | 13 | 1,338 | 2,811 | 1,012 |
| " | 14 | 1,448 | 2,652 | 1,046 |
| " | 15 | 1,517 | 2,411 | 1,109 |
| " | 16 | 1,650 | 2,049 | 1,232 |
| " | 17 | 1,813 | 2,143 | 1,240 |
| " | 18 | 1,959 | 2,258 | 1,259 |
| " | 19 | 2,185 | 2,093 | 1,311 |
| " | 20 | 2,462 | 2,271 | 1,446 |
| " | 21 | 3,850 | 2,582 | 1,625 |
| " | 22 | 5,100 | 2,525 | 1,547 |
| " | 23 | 2,462 | 2,490 | 1,584 |
| " | 24 | 2,008 | 2,884 | 1,625 |
| " | 25 | 2,236 | 2,939 | 1,720 |
| " | 26 | 2,321 | 3,250 | 1,804 |
| " | 27 | 2,422 | 3,561 | 1,890 |
| " | 28 | —— | 4,071 | 1,985 |

Or averages for the week:

| DATE | 1901. | 1900. | NORMAL. |
|---|---|---|---|
| April 24—30 | 416 | 1,731 | 532 |
| May 1—7 | 708 | 2,431 | 661 |
| May 8—14 | 1,096 | 2,759 | 973 |
| May 15—21 | 2,205 | 2,258 | 1,317 |
| May 22—28 | 2,759 | 3,103 | 1,729 |

The preceeding years average for the same weeks as follows:

| YEAR. | APRIL 24-30. | MAY 1-7. | MAY 8-14. | MAY 15-22. |
|---|---|---|---|---|
| 1884 | 562 | 497 | 1,528 | 3,499 |
| 1885 | 607 | 1,131 | 1,481 | 1,416 |
| 1886 | 405 | 567 | 878 | 1 084 |
| 1887 | —— | —— | —— | 1,655 |
| 1888 | 304 | 304 | 379 | 636 |
| 1889 | 233 | 275 | 345 | 851 |
| 1890 | 417 | 609 | 758 | 1,027 |
| 1891 | 299 | 682 | 953 | 1,096 |
| 1892 | —— | 200 | 214 | 265 |
| 1893 | —— | 200 | 250 | 756 |
| 1894 | —— | 568 | 1,303 | 1,704 |
| 1895 | 680 | 684 | 1,230 | 1,287 |
| 1896 | —— | 549 | 826 | 530 |
| 1897 | 594 | 1,122 | 1,391 | 2,213 |
| 1898 | 253 | 249 | 423 | 763 |
| 1899 | 504 | 515 | 851 | 1,554 |
| 1900 | 1,731 | 2,431 | 2,759 | 2,258 |
| 1901 | 416 | 708 | 1,096 | 1,931 |

The river has thus been above the normal so far this year, but less than last year which is known as an exceptional flow on account of the heavy precipitation in April.

The snow during the winter was late, and the indications early in the season was that late water would be short. The exceptionally warm weather of last week causing rapid meltings at high elevations led to rapid decrease of snow fields. The river at Home, elevation 7,500 feet, was reported by Mr. Zimmerman as being higher than he had ever seen it, and this was due to the snow and not to the storm which at the same time fell at the lower elevation.

The precipitation to May 1st was above the normal, reaching 3.62 inches in April, and a total of 6.07 inches to May 1st. The normal at the same time is 4.21 inches. The normal for May is 2.74 inches, to date it is 6.70 inches of which 5.60 inches fell on May 20 and 21, 3.24 inches the afternoon and evening of May 20, and 2.36 inches the evening of May 21. Those were accompanied by hail and were the severest storms of which we have record at the agricultural college. The floods produced were severe and destructive. The second day's storm extended over a greater extent of the country in the mountains, and raised the river on the night of May 21 to a depth of 7.46 feet, or an estimated flow of about 12,000 cubic feet per second. This soon subsided, having fallen to less than 4,500 feet by noon on Wednesday, and to 2,500 feet by Thursday noon.

L. G. CARPENTER.

No. 2. 1901

# Special River Bulletin.

# The Agricultural Experiment Station

FORT COLLINS, COLORADO.

## Poudre River Bulletin.

### May 29 to June 4.

During the week the river has fallen slightly, so that there was about 500 cubic feet per second less at the close of the week under consideration than there was at the beginning. This is slightly less than the normal, although the week as a whole averaged above the normal. The indication is that the river has now passed its highest stage, and unless there are frequent rains the probabilities are that there will be a rapid decrease of water in the river. It will certainly be much less than in 1900, and in all probability less than the normal, during the rest of the season. The following is the record for the past week:

| DATE. | 1901. | 1900. | NORMAL. |
|---|---|---|---|
| May 29 | 2,570 | 4,560 | 1,980 |
| " 30 | 2,216 | 4,416 | 2,046 |
| " 31 | 2.574 | 4,204 | 2.028 |
| June 1 | 2,449 | 3,951 | 2,052 |
| " 2 | 2,263 | 3,938 | 2,120 |
| " 3 | 2,199 | 4,080 | 2,250 |
| " 4 | 2,010 | 3,600 | 2,207 |
| Average | 2,326 | 4,107 | 2,098 |

The preceeding years' average for the same week is as follows:

| | | | | | |
|---|---|---|---|---|---|
| 1884 | 3,881 | 1890 | 1,630 | 1896 | 1,829 |
| 1885 | 2,641 | 1891 | 1,914 | 1897 | 2,372 |
| 1886 | 2,417 | 1892 | 1,011 | 1898 | 1,291 |
| 1887 | 2,404 | 1893 | 1,025 | 1899 | 1,846 |
| 1888 | 994 | 1894 | 2,668 | 1900 | 4,107 |
| 1889 | 1,606 | 1895 | 2,022 | 1901 | 2,326 |

The rainfall during May has been exceptional, amounting to 7.47 inches, while the normal is 2.74. The total rainfall since the first of the year is 13.54, while the normal for the same time is 6.95.

The normal flow for the week from June 5 to 11, is 2,219 cubic feet per second.

L. G. CARPENTER.

No. 3. 1901

# Special River Bulletin.

# The Agricultural Experiment Station

FORT COLLINS, COLORADO.

## Poudre River Bulletin.

### June 5 to June 11.

The cloudy weather which was prevalent on the plains during the early part of last week evidently resulted in storms in the mountains, and the melting of the snow after the clear weather of Friday caused a rise in the stream, which reached its highest on Saturday. It then amounted to nearly twenty-six hundred cubic feet per second. Since that time the flow has gradually decreased. In consequence of this rise the last three days of this record have been nearly normal. As a whole the week has been about 10 per cent. less than the normal, and only about one half of the corresponding week of last year. Aside from that it is greater than any year since 1895.

The following is the record for the past week:

| DATE. | 1901. | 1900. | NORMAL. |
|---|---|---|---|
| June 5 | 1,870 | 3,104 | 2,108 |
| " 6 | 1,695 | 3,602 | 2,149 |
| " 7 | 1.733 | 4,376 | 2.136 |
| " 8 | 1,951 | 4,227 | 2,165 |
| " 9 | 2,240 | 4,193 | 2,268 |
| " 10 | 2,182 | 4,180 | 2,385 |
| " 11 | 2,135 | 3,224 | 2,319 |
| Average | 1,972 | 3,844 | 2,219 |

The preceeding years' average for the same week is as follows:

| | | | | | |
|---|---|---|---|---|---|
| 1884 | 4,975 | 1890 | 1,213 | 1896 | 1,316 |
| 1885 | 2,767 | 1891 | 2,505 | 1897 | 1,753 |
| 1886 | 2,423 | 1892 | 1,276 | 1898 | 1,226 |
| 1887 | 2,314 | 1893 | 1.858 | 1899 | 1,892 |
| 1888 | 1,271 | 1894 | 2,778 | 1900 | 3,844 |
| 1889 | 1,443 | 1895 | 2,855 | 1901 | 1,972 |

The rainfall during the week has amounted to 0.29 inches at the college, but has been much heavier in places near by. The total rainfall in June, so far, has been 0.51 inches, while the normal for the month is 1.57.

The normal flow of the river for next week is 2,140 cubic feet per second.

L. G. CARPENTER.

No. 4. 1901

# Special River Bulletin.

# The Agricultural Experiment Station

FORT COLLINS, COLORADO.

## Poudre River Bulletin.

### June 12 to June 18.

The flow of the river for the past week has averaged 1,953 cubic feet per second, reaching its maximum on Saturday. This is less than the normal, notwithstanding the heavy rainfall of the week.

A comparison with the records for the same week of other years shows that nine have averaged more, and eight less, than the flow recorded.

The following is the record for the past week:

| DATE. | 1901. | 1900. | NORMAL. |
|---|---|---|---|
| June 12 | 1,854 | 2,978 | 2,271 |
| " 13 | 1,753 | 2,818 | 2,227 |
| " 14 | 1,823 | 3,001 | 2,188 |
| " 15 | 2,127 | 2,797 | 2,171 |
| " 16 | 2,123 | 2,968 | 2,128 |
| " 17 | 2,049 | 2,923 | 2,038 |
| " 18 | 1,940 | 2,622 | 1,959 |
| Average | 1,953 | 2,872 | 2,140 |

The preceeding years' average for the same week is as follows:

| | | | | | |
|---|---|---|---|---|---|
| 1884 | 4,904 | 1890 | 1,274 | 1896 | 1,075 |
| 1885 | 2,636 | 1891 | 1,844 | 1897 | 2,082 |
| 1886 | 1,999 | 1892 | 1,356 | 1898 | 1,519 |
| 1887 | 1,861 | 1893 | 2,395 | 1899 | 3,017 |
| 1888 | 1,317 | 1894 | 2,101 | 1900 | 2,872 |
| 1889 | 1,433 | 1895 | 2,688 | 1901 | 1,958 |

The rainfall at the college has amounted to 1.84 inches for the week. The total rainfall for the month, so far, has been 2.35, while the normal for June is only 1.57.

The normal flow of the river for next week is 1,873 cubic feet per second.

L. G. CARPENTER.

No. 5. 1901

Special River Bulletin.

The Agricultural Experiment Station

FORT COLLINS, COLORADO.

# Poudre River Bulletin.

### June 19 to June 25.

Following the general rains in the mountains on the 14th and 15th and a heavy storm near the head waters on the 17th, and the cloudy weather accompanying them, the river during the first of the week fell below normal, though only by a small amount. During the latter part of the week the temperature ran above normal by several degrees, and this has increased the melting of the snow, so that the river has been slightly above the normal for the whole week. It has averaged nearly 150 feet above normal for the same period, but is still over 400 feet less than for the same week of last year. While there is still a considerable amount of snow left, most of it is in such form that it will melt fast, and the indications are that the river will fall below normal unless maintained by timely rains. So far this year the flow of the river has been exceptionally good.

The following is the record for the past week:

| DATE. | 1901. | 1900. | NORMAL. |
|---|---|---|---|
| June 19 | 1,970 | 2,789 | 2,005 |
| “ 20 | 1,913 | 2,567 | 1,913 |
| “ 21 | 1,997 | 2,573 | 1,966 |
| “ 22 | 2,087 | 2,441 | 1,881 |
| ‘ 23 | 2,144 | 2,460 | 1,810 |
| “ 24 | 2,136 | 2,829 | 1,783 |
| “ 25 | 2,065 | 2,140 | 1,755 |
| Average | 2,045 | 2,471 | 1,873 |

The preceeding years' average for the same week is as follows:

| | | | | | |
|---|---|---|---|---|---|
| 1881 | 1,070 | 1890 | 1,257 | 1896 | 818 |
| 1884 | 4,708 | 1891 | 1,612 | 1897 | 1,434 |
| 1885 | 3,171 | 1892 | 2,141 | 1898 | 1,418 |
| 1886 | 1,327 | 1893 | 1,982 | 1899 | 3,298 |
| 1887 | 1,329 | 1894 | 1,466 | 1900 | 2,471 |
| 1888 | 999 | 1895 | 1,841 | 1901 | 2,045 |
| 1889 | 1,303 | | | | |

The normal flow of the river for next week is 1,550 cubic feet per second.

L. G. CARPENTER.

No. 6. 1901

Special River Bulletin.

# The Agricultural Experiment Station

FORT COLLINS, COLORADO.

## Poudre River Bulletin.

### June 26 to July 2.

The flow of the river during the week has been nearly normal, and also nearly the same as it was in 1900, but only about one half of the amount for the same week in 1899. It compares favorably with the other years, with the exception of 1884 and 1885, which very much exceeded this amount.

Because someone meddled with the instrument a little before ten o'clock on Saturday morning, the record for the last three days is partially an estimate, but is nearly correct.

The following is the record for the past week:

| DATE. | 1901. | 1900. | NORMAL. |
|---|---|---|---|
| June 26 | 1,811 | 2,036 | 1,741 |
| “ 27 | 1,675 | 1,813 | 1,633 |
| “ 28 | 1,575 | 1,674 | 1,619 |
| “ 29 | *1,497 | 1,540 | 1,561 |
| “ 30 | *1,425 | 1,325 | 1,472 |
| July 1 | *1,455 | 1,360 | 1,426 |
| “ 2 | *1,362 | 1,276 | 1,399 |
| Average | 1,543 | 1,575 | 1,550 |

* Estimated.

The preceding years' average for the same week is as follows:

| | | | | | |
|---|---|---|---|---|---|
| 1881 | 1,491 | 1890 | 1,067 | 1896 | 616 |
| 1884 | 4,938 | 1891 | 1,083 | 1897 | 1,126 |
| 1885 | 2,883 | 1892 | 2,519 | 1898 | 890 |
| 1886 | 1,272 | 1893 | 1,191 | 1899 | 2,692 |
| 1887 | 1,091 | 1894 | 1,127 | 1900 | 1,575 |
| 1888 | 704 | 1895 | 1,758 | 1901 | 1,543 |
| 1889 | 886 | | | | |

L. G. CARPENTER.

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FORT COLLINS, COLORADO.

# Poudre River Bulletin.

### July 3 to July 9.

During the week the flow of the river has gradually but steadily diminished, falling from nearly 1,300 cubic feet per second on July 3, to 800 at the end. It is now below the normal amount for the corresponding date. There has been a lack of rain, and is need of water.

The following is the record for the past week:

| DATE. | 1901. | 1900. | NORMAL. |
|---|---|---|---|
| July 3 | 1,289 | 1,176 | 1,328 |
| " 4 | 1,164 | 1,042 | 1,290 |
| " 5 | 1,062 | 958 | 1,213 |
| " 6 | 1,028 | 871 | 1,152 |
| " 7 | 997 | 853 | 1,154 |
| " 8 | 914 | 827 | 1,118 |
| " 9 | 800 | 795 | 1,089 |
| Average | 1,036 | 932 | 1,189 |

The corresponding week in previous years has averaged, in cubic feet per second:

| | | | | | |
|---|---|---|---|---|---|
| 1881 | 1,411 | 1890 | 841 | 1897 | 893 |
| 1884 | 3,542 | 1891 | 852 | 1898 | 601 |
| 1885 | 2,542 | 1892 | 973 | 1899 | 2,070 |
| 1886 | 963 | 1893 | 893 | 1900 | 932 |
| 1887 | 788 | 1894 | 1,105 | 1901 | 1,036 |
| 1888 | 540 | 1895 | 1,266 | | |
| 1889 | 701 | 1896 | 474 | | |

The river normal for next week is 920 cubic feet per second.

L. G. CARPENTER.

No. 8. 1901

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FORT COLLINS, COLORADO.

# Poudre River Bulletin.

## July 10 to July 16.

At the beginning of the week the river rose to 1,150 cubic feet per second, and continued above the normal until the 12th, after which date it fell rapidly, registering, but 750 cubic feet per second at the close. The average for the week is slightly above the normal, and nearly 300 feet more than that for the corresponding week in 1900.

The following is the record for the past week:

| DATE. | 1901. | 1900. | NORMAL. |
|---|---|---|---|
| July 10 | 1,150 | 752 | 1,029 |
| " 11 | 1,083 | 705 | 954 |
| " 12 | 1,077 | 666 | 965 |
| " 13 | 948 | 641 | 951 |
| " 14 | 854 | 625 | 871 |
| " 15 | 792 | 597 | 856 |
| " 16 | 747 | 599 | 814 |
| Average | 950 | 655 | 920 |

The corresponding week in previous years has averaged, in cubic feet per second:

| | | | | | |
|---|---|---|---|---|---|
| 1881 | 761 | 1890 | 624 | 1897 | 907 |
| 1884 | 2,229 | 1891 | 563 | 1898 | 658 |
| 1885 | 1,887 | 1892 | 837 | 1899 | 1,509 |
| 1886 | 690 | 1893 | 626 | 1900 | 655 |
| 1887 | 904 | 1894 | 960 | 1901 | 950 |
| 1888 | 439 | 1895 | 1,347 | | |
| 1889 | 563 | 1896 | 405 | | |

L. G. CARPENTER.

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FORT COLLINS, COLORADO.

# Poudre River Bulletin.

### July 17 to July 23.

The river has continued to decrease during the week, but has not fallen below the normal. This is partly due to the fact that a considerable quantity of water is still coming across the range from other watersheds than the Poudre. On Friday this was reported to be 127 cubic feet per second, and it was more earlier in the week. If this amount be deducted from the quantity in the river as reported, the flow is considerably below the normal. It, however, compares favorably with most former years, as shown in the record for the corresponding week in previous years.

While the precipitation in June was above the normal there has been no precipitation of any amount since the 15th of June, the only exception is a total rain of .24 inches on July 10th and 14th. The temperature has been abnormally high. The highest at Fort Collins has been 96 degrees, which has been reached on two days, and 90 degrees has been reached on sixteen days out of twenty three. The temperature at night, however, has fallen to below 60 degrees. With the quantity of water available in the streams the crops are doing well.

The following is the record for the past week:

| DATE. | 1901. | 1900. | NORMAL. |
|---|---|---|---|
| July 17 | 621 | 576 | 794 |
| " 18 | 600 | 531 | 774 |
| " 19 | 595 | 525 | 737 |
| " 20 | 601 | 525 | 694 |
| " 21 | 578 | 481 | 704 |
| " 22 | 568 | 460 | 650 |
| " 23 | 558 | 475 | 611 |
| Average | 589 | 510 | 709 |

The corresponding week in previous years has averaged, in cubic feet per second:

| | | | | | |
|---|---|---|---|---|---|
| 1881 | 717 | 1890 | 679 | 1897 | 697 |
| 1884 | 1,454 | 1891 | 409 | 1898 | 374 |
| 1885 | 1,578 | 1892 | 576 | 1899 | 1,031 |
| 1886 | 651 | 1893 | 445 | 1900 | 510 |
| 1887 | 789 | 1894 | 727 | 1901 | 589 |
| 1888 | 311 | 1895 | 995 | | |
| 1889 | 370 | 1896 | 452 | | |

The normal flow of the river for next week is 719 cubic feet per second.

L. G. CARPENTER.

No. 11. 1901

# Special River Bulletin.

The Agricultural Experiment Station

FORT COLLINS, COLORADO.

## Poudre River Bulletin.

### July 31 to August 6.

During the week the river has remained nearly constant, but with a slight decrease, changing from 406 cubic feet per second at the beginning to 380 at the close. This includes the water coming from across the range. Most of the reservoirs are now being drawn on for water.

The following is the record for the past week:

| DATE. | 1901. | 1900. | NORMAL. |
|---|---|---|---|
| July 31 | 406 | 506 | 502 |
| Aug. 1 | 382 | 369 | 490 |
| " 2 | 369 | 355 | 485 |
| " 3 | 371 | 341 | 479 |
| " 4 | 377 | 374 | 469 |
| " 5 | 380 | 430 | 438 |
| " 6 | — | — | — |
| Average | 381 | 401 | 471 |

The corresponding week in previous years has averaged, in cubic feet per second:

| | | | | | |
|---|---|---|---|---|---|
| 1881 | — | 1890 | 305 | 1897 | 552 |
| 1884 | 1,031 | 1891 | 277 | 1898 | 194 |
| 1885 | 1,015 | 1892 | 304 | 1899 | 847 |
| 1886 | 315 | 1893 | 305 | 1900 | 401 |
| 1887 | 396 | 1894 | 449 | 1901 | 381 |
| 1888 | 354 | 1895 | 733 | | |
| 1889 | 358 | 1896 | 287 | | |

L. G. CARPENTER.

No. 12. 1901

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# The Agricultural Experiment Station

FORT COLLINS, COLORADO.

## Poudre River Bulletin.

### August 7 to August 13.

The following summary gives the river by weeks during the present season in comparison with the corresponding weeks in previous years. It will be seen that the record for the year has been a very satisfactory one.

| WEEK | 1901. | 1900. | NORMAL |
|---|---|---|---|
| May 22-28 | 2,759 | 3,108 | 1,729 |
| May 29-June 4 | 2,326 | 4,107 | 2,098 |
| June 5-11 | 1,972 | 3,944 | 2,219 |
| June 12-18 | 1,953 | 2,872 | 2,140 |
| June 19-25 | 2,045 | 2,471 | 1,873 |
| June 26-July 2 | 1,543 | 1,575 | 1,550 |
| July 3-9 | 1,036 | 932 | 1,189 |
| July 10-16 | 950 | 655 | 920 |
| July 17-23 | 589 | 510 | 709 |
| July 31-August 6 | 381 | 401 | 471 |
| August 7-13 | 416 | 297 | 380 |

It may be interesting to the users of these reports to know how the quantities are derived. Gagings are made on the river at different heights, varying from low water up to high water, and the quantities found correspond to different depths. From this data what is known as the rating table for the river is constructed. During the past few years over forty such gagings have been made, and these form the basis for the determination. It is found that there has been comparatively little change in the river for the past ten years, and the measurements thus made apply quite closely to the present conditions. These measurements have been checked many times. While such measurements are subject to errors, yet they have agreed among themselves very closely. It is not impossible for discrepancies of five per cent. to occur, even under fairly careful measurements. Yet as an indication of the accuracy it may be stated that at the last measurement a week ago the amount found at the gaging point was 332 cubic feet per second; the amount taken by various ditches was 249.3 cubic feet per second, and on measuring there was found to be 79 feet still in the river. This leaves a difference of 3.7 cubic feet per second, which may be due to a loss in that section which we have sometimes found, or might be an error of observation.

These river measurements were made by R. E. Trimble.

The following is the record for the past week:

| DATE. | 1901. | 1900. | NORMAL. |
|---|---|---|---|
| Aug. 7 | 368 | 392 | 414 |
| " 8 | 483 | 315 | 383 |
| " 9 | 510 | 299 | 395 |
| " 10 | 443 | 292 | 398 |
| " 11 | 366 | 276 | 374 |
| " 12 | 393 | 260 | 358 |
| " 13 | 346 | 247 | 339 |
| Average | 416 | 297 | 380 |

The corresponding week in previous years has averaged, in cubic feet per second:

| | | | | | |
|---|---|---|---|---|---|
| 1881 | —— | 1890 | 285 | 1897 | 481 |
| 1884 | 833 | 1891 | 200 | 1898 | 181 |
| 1885 | 783 | 1892 | 262 | 1899 | 711 |
| 1886 | 246 | 1893 | 289 | 1900 | 297 |
| 1887 | 293 | 1894 | 446 | 1901 | 416 |
| 1888 | 189 | 1895 | 566 | | |
| 1889 | 195 | 1896 | 203 | | |

L. G. CARPENTER.

No. 13. 1901
Special River Bulletin.

# The Agricultural Experiment Station

FORT COLLINS, COLORADO.

## Poudre River Bulletin.

**August 14 to August 20.**

During the past week the river has maintained a flow rather better than for the corresponding week of last year, and nearly the same as the normal. The amount for this period includes, however, some water from the other watersheds, averaging about 50 cubic feet per second. As compared with other years this has been noticeably exceeded by only four out of eighteen years' record.

The following is the record for the past week:

| DATE. | 1901. | 1900. | NORMAL. |
|---|---|---|---|
| Aug. 14 | 333 | 235 | 338 |
| " 15 | 306 | 214 | 324 |
| " 16 | 304 | 218 | 338 |
| " 17 | 304 | 218 | 325 |
| " 18 | 309 | 218 | 337 |
| " 19 | 313 | 214 | 333 |
| " 20 | 314 | 212 | 317 |
| Average | 312 | 218 | 337 |

The corresponding week in previous years has averaged, in cubic feet per second:

| | | | | | |
|---|---|---|---|---|---|
| 1881 | — | 1890 | 375 | 1897 | 333 |
| 1884 | 358 | 1891 | 219 | 1898 | 127 |
| 1885 | 502 | 1892 | 187 | 1899 | 502 |
| 1886 | 338 | 1893 | 245 | 1900 | 218 |
| 1887 | 321 | 1894 | 325 | 1901 | 312 |
| 1888 | 197 | 1895 | 442 | | |
| 1889 | 161 | 1896 | 255 | | |

The rainfall for the week was 0.29 inches. The normal flow of the river for the coming week is 282 cubic feet per second.

L. G. Carpenter.

No. 14. 1901

Special River Bulletin.

# The Agricultural Experiment Station

FORT COLLINS, COLORADO.

## Poudre River Bulletin.

### August 21 to August 27.

The discharge of the river during the past week has decreased but slightly, owing to showers in the mountains. The average has been 291, including the water from the Laramie river. The average for seventeen years has been 282 cubic feet per second. Small showers have occurred on the plains during the past week, but have done very little good.

The following is the record for the past week:

| DATE. | 1901. | 1900. | NORMAL. |
|---|---|---|---|
| Aug. 21 | 353 | 210 | 306 |
| " 22 | 303 | 248 | 299 |
| " 23 | 274 | 195 | 291 |
| " 24 | 265 | 200 | 284 |
| " 25 | 259 | 198 | 280 |
| " 26 | 290 | 215 | 262 |
| " 27 | 294 | 212 | 251 |
| Average | 291 | 211 | 282 |

The corresponding week in previous years has averaged, in cubic feet per second:

| | | | | | |
|---|---|---|---|---|---|
| 1881 | —— | 1890 | 274 | 1897 | 233 |
| 1884 | 654 | 1891 | 250 | 1898 | 187 |
| 1885 | 529 | 1892 | 146 | 1899 | 334 |
| 1886 | 339 | 1893 | 203 | 1900 | 211 |
| 1887 | 256 | 1894 | 244 | 1901 | 291 |
| 1888 | 131 | 1895 | 377 | | |
| 1889 | 138 | 1896 | 419 | | |

L. G. CARPENTER.

No. 15. 1901

Special River Bulletin.

The Agricultural Experiment Station

FORT COLLINS, COLORADO.

# Poudre River Bulletin.

### August 27 to Sept. 3.

The river has averaged 282 cubic feet per second as compared with 196 feet for the corresponding period last year, and 243 feet for the normal. The amount available for distribution is above the normal, but as the amount this year includes about 100 cubic feet per second from other watersheds, there is probably a shortage in the ordinary river supply.

The following is the record for the past week:

| DATE. | 1901. | 1900. | NORMAL. |
|---|---|---|---|
| Aug. 28 | 242 | 201 | 252 |
| " 29 | 269 | 204 | 251 |
| " 30 | 266 | 199 | 240 |
| " 31 | 301 | 204 | 247 |
| Sept 1 | 294 | 204 | 245 |
| " 2 | 273 | 199 | 238 |
| ' 3 | ......... | 160 | 228 |
| Average | 282 | 196 | 243 |

The corresponding week in previous years has averaged, in cubic feet per second:

| | | | | | |
|---|---|---|---|---|---|
| 1881 | —— | 1890 | 164 | 1897 | 302 |
| 1884 | 454 | 1891 | 170 | 1898 | 233 |
| 1885 | 372 | 1892 | ... | 1899 | 121 |
| 1886 | 304 | 1893 | 152 | 1900 | 375 |
| 1887 | 292 | 1894 | 174 | 1901 | 196 |
| 1888 | 140 | 1895 | 341 | | |
| 1889 | 75 | 1896 | 419 | | |

L. G. CARPENTER.

No. 16. 1901

## Special River Bulletin.

# The Agricultural Experiment Station

FORT COLLINS, COLORADO.

## Poudre River Bulletin.

### Sept. 4 to Sept. 10.

During the past week the flow of the river has steadily decreased from 265 cubic feet per second on September 3rd, to 128 cubic feet per second at the close of the week. This decrease has been uniformly distributed through the week.

There has been a rainfall of 2¼ inches during the week at the agricultural college, and heavy rains in the neighboring localities.

L. G. CARPENTER.

No. 17. 1901
Special River Bulletin.

# The Agricultural Experiment Station

FORT COLLINS, COLORADO.

## Poudre River Bulletin.

### Sept. 11 to Sept. 17.

During the week the flow of the river has slightly diminished. There was an average of 137 cubic feet. The normal was 177 cubic feet.

No precipitation has fallen at the agricultural college during the past week.

The following is the record of the week in second feet:

| DATE. | 1901. | 1900. | NORMAL. |
|---|---|---|---|
| Sept. 11 | 158 | 255 | 204 |
| " 12 | 188 | 151 | 189 |
| " 13 | 134 | 157 | 182 |
| " 14 | 134 | 156 | 170 |
| " 15 | 134 | 144 | 166 |
| " 16 | 134 | 138 | 168 |
| " 17 | 131 | 133 | 161 |
| Average | 137 | 162 | 177 |

The corresponding week in previous years has averaged in second feet:

| | | | | | |
|---|---|---|---|---|---|
| 1881 | —— | 1890 | 93 | 1897 | 170 |
| 1884 | 313 | 1891 | 131 | 1898 | 71 |
| 1885 | 285 | 1892 | ... | 1899 | 211 |
| 1886 | 183 | 1893 | ... | 1900 | ... |
| 1887 | 151 | 1894 | 199 | 1901 | ... |
| 1888 | 104 | 1895 | 191 | | |
| 1889 | 64 | 1896 | 329 | | |

L. G. Carpenter.

No. 18. 1901

# Special River Bulletin.

# The Agricultural Experiment Station

FORT COLLINS, COLORADO.

## Poudre River Bulletin.

### Sept. 18 to Sept. 24.

The discharge of the river for the past week has been slightly lower, the average for the week being 109 cubic feet, while the normal for the same time is 145 cubic feet. There has been no precipitation at the college during the past week. Several frosts were recorded the first of the week.

The following is the record of the week in second feet:

| DATE. | 1901. | 1900. | NORMAL. |
|---|---|---|---|
| Sept. 18 | 113 | — | 154 |
| " 19 | 111 | 118 | 151 |
| " 20 | 111 | 113 | 146 |
| " 21 | 111 | 122 | 144 |
| " 22 | 110 | 122 | 140 |
| " 23 | 106 | 121 | 139 |
| " 24 | 104 | 121 | 144 |
| Average | 109 | 118 | 145 |

The corresponding week in previous years has averaged in second feet:

| | | | | | |
|---|---|---|---|---|---|
| 1881 | — | 1890 | 83 | 1897 | 154 |
| 1884 | 229 | 1891 | 130 | 1898 | 47 |
| 1885 | 221 | 1892 | ... | 1899 | 155 |
| 1886 | 140 | 1893 | ... | 1900 | 118 |
| 1887 | 125 | 1894 | 125 | 1901 | 109 |
| 1888 | 83 | 1895 | 198 | | |
| 1889 | 73 | 1896 | 274 | | |

L. G. CARPENTER.

No. 19. 1901

Special River Bulletin.

The Agricultural Experiment Station

FORT COLLINS, COLORADO.

# Poudre River Bulletin.

### Sept. 25 to Oct. 1.

The average during the past week has been 105 cubic feet per second, of which, 13 feet is reported by the water commissioner as coming from other water sheds, leaving 92 feet due to the river proper. The normal for the same period is 144 feet. This includes water from other water sheds during the past few years.

There has been no precipitation at the college during the past week. The precipitation during the month of September amounted to 2.10 inches.

The following is the record of the week in second feet:

| DATE. | 1901. | 1900. | NORMAL. |
|---|---|---|---|
| Sept. 25 | 102 | 126 | 148 |
| " 26 | 101 | 141 | 147 |
| " 27 | 98 | 144 | 148 |
| " 28 | 100 | 140 | 145 |
| " 29 | 110 | 140 | 143 |
| " 30 | 113 | 141 | 141 |
| Oct. 1 | 109 | 140 | 147 |
| Average | 105 | 139 | 144 |

The corresponding week in previous years has averaged in second feet:

| | | | | | |
|---|---|---|---|---|---|
| 1881 | —— | 1890 | 67 | 1897 | 142 |
| 1884 | 240 | 1891 | 146 | 1898 | 35 |
| 1885 | 214 | 1892 | ... | 1899 | 131 |
| 1886 | 138 | 1893 | ... | 1900 | 144 |
| 1887 | 153 | 1894 | 119 | 1901 | 105 |
| 1888 | 83 | 1895 | 199 | | |
| 1889 | 70 | 1896 | 284 | | |

L. G. CARPENTER.

No. 20. 1901

## Special River Bulletin.

# The Agricultural Experiment Station

FORT COLLINS, COLORADO.

## Poudre River Bulletin.

### Oct. 2 to Oct. 8.

The river has shown a slight gain durthe latter part of the week, owing to the precipitation of .36 inches during the week. The average for the week is 110 cubic feet per second. The normal is 134 feet.

The following is the record of the week in second feet:

| DATE. | 1901. | 1900. | NORMAL. |
|---|---|---|---|
| Oct. 2 | 103 | 137 | 137 |
| " 3 | 100 | 126 | 133 |
| " 4 | 93 | 118 | 137 |
| " 5 | 110 | 114 | 133 |
| " 6 | 116 | 116 | 131 |
| " 7 | 122 | 131 | 132 |
| " 8 | 126 | 120 | 133 |
| Average | 110 | 123 | 134 |

The corresponding week in previous years has averaged in second feet:

| | | | | | |
|---|---|---|---|---|---|
| 1881 | — | 1890 | 64 | 1897 | 133 |
| 1884 | 204 | 1891 | 137 | 1898 | 38 |
| 1885 | 203 | 1892 | ... | 1899 | 101 |
| 1886 | 133 | 1893 | ... | 1900 | 122 |
| 1887 | 126 | 1894 | 142 | 1901 | 110 |
| 1888 | 96 | 1895 | 224 | | |
| 1889 | 69 | 1896 | 218 | | |

L. G. Carpenter.

No. 21. 1901

Special River Bulletin.

The Agricultural Experiment Station

FORT COLLINS, COLORADO.

# Poudre River Bulletin.

### Oct. 9 to Oct. 15.

The discharge of the river during the past week has fallen but slightly from that at the beginning of the week. It has averaged 129 cubic feet, while the average of the corresponding week last year was 139 cubic feet, and the normal for the week is 130 cubic feet.

Only a trace of precipitation has fallen at the college.

The following summary gives the flow and comparison by weeks with that of 1900 and the normal:

| WEEK. | | 1901 | 1900 | NORMAL |
|---|---|---|---|---|
| May | 22 to 28 | 2759 | 3103 | 1729 |
| " | 29 to June 4 | 2326 | 4107 | 2098 |
| June | 5 to 11 | 1972 | 3944 | 2219 |
| " | 12 to 18 | 1953 | 2872 | 2140 |
| " | 19 to 25 | 2045 | 2471 | 1873 |
| " | 26 to July 2 | 1543 | 1575 | 1550 |
| July | 3 to 9 | 1036 | 932 | 1189 |
| " | 10 to 16 | 950 | 655 | 920 |
| " | 17 to 23 | 589 | 510 | 709 |
| " | 24 to 30 | 508 | 649 | 551 |
| " | 31 to Aug. 6 | 381 | 401 | 471 |
| Aug. | 7 to 13 | 416 | 297 | 380 |
| " | 14 to 20 | 312 | 218 | 337 |
| " | 21 to 27 | 291 | 211 | 282 |
| " | 28 to Sept. 3 | 282 | 196 | 243 |
| Sept. | 4 to 10 | 215 | 158 | 203 |
| " | 11 to 17 | 137 | 162 | 177 |
| " | 18 to 24 | 109 | 118 | 145 |
| " | 25 to Oct. 1 | 105 | 139 | 144 |
| Oct. | 2 to 8 | 110 | 123 | 134 |
| " | 9 to 15 | 129 | 139 | 130 |
| Average | | 865 | 1094 | 839 |

The following is the record of the week in second feet:

| DATE. | | 1901. | 1900. | NORMAL. |
|---|---|---|---|---|
| Oct. | 9 | 136 | 119 | 130 |
| " | 10 | 135 | 149 | 139 |
| " | 11 | 133 | 165 | 129 |
| " | 12 | 129 | 138 | 129 |
| " | 13 | 126 | 139 | 132 |
| " | 14 | 122 | 135 | 130 |
| " | 15 | 120 | 130 | 127 |
| Average | | 129 | 139 | 130 |

The corresponding week in previous years has averaged in second feet:

| | | | | | |
|---|---|---|---|---|---|
| 1881 | — | 1890 | 94 | 1897 | 121 |
| 1884 | 204 | 1891 | 114 | 1898 | 60 |
| 1885 | 204 | 1892 | ... | 1899 | 152 |
| 1886 | 125 | 1893 | ... | 1900 | 139 |
| 1887 | 117 | 1894 | 110 | 1901 | 129 |
| 1888 | 62 | 1895 | 186 | | |
| 1889 | 62 | 1896 | 213 | | |

L. G. CARPENTER.

# THE STATE AGRICULTURAL COLLEGE OF COLORADO

# THE FOURTEENTH ANNUAL REPORT

OF

# The Agricultural Experiment Station

For 1901

# LETTER OF TRANSMITTAL.

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To His Excellency,
JAMES B. ORMAN,
Governor of Colorado.

In accordance with the conditions of the act of Congress which requires a full and detailed report of the operations of the Experiment Station, I have the honor to present herewith the Fourteenth Annual Report.

The financial statement is for the United States fiscal year ending June 30; the other portions being reported substantially for the current year.

L. G. CARPENTER, Director.

# The Agricultural Experiment Station,

## FORT COLLINS, COLORADO.

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## THE STATE BOARD OF AGRICULTURE.

| | | Term Expires |
|---|---|---|
| HON. B. F. ROCKAFELLOW, | Canon City. | 1903 |
| MRS. ELIZA F. ROUTT, | Denver. | 1903 |
| HON. P. F. SHARP, *President*, | Denver. | 1905 |
| HON. JESSE HARRIS, | Fort Collins. | 1905 |
| HON. HARLAN THOMAS, | Denver. | 1907 |
| *HON. P. A. AMISS, | Pruden. | |
| †HON. W. R. THOMAS, | Denver. | 1907 |
| HON. JAMES L. CHATFIELD, | Gypsum. | 1909 |
| HON. B. U. DYE, | Rockyford. | 1909 |

GOVERNOR JAMES B. ORMAN, } *ex-officio*.
PRESIDENT BARTON O. AYLESWORTH, } *ex-officio*.

* Resigned April, 1901.
† Elected by the Board to fill vacancy.

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### EXECUTIVE COMMITTEE—TO APRIL 30.

P. F. SHARP, *Chairman*. B. F. ROCKAFELLOW.
P. A. AMISS. JAMES L. CHATFIELD. JESSE HARRIS.

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### EXECUTIVE COMMITTEE IN CHARGE.

P. F. SHARP, *Chairman*.
B. F. ROCKAFELLOW. JESSE HARRIS.

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## STATION STAFF.

| | |
|---|---|
| L. G. CARPENTER, M. S., *Director*, | IRRIGATION ENGINEER |
| C. P. GILLETTE, M. S., | ENTOMOLOGIST |
| W. P. HEADDEN, A. M., PH. D., | CHEMIST |
| WENDELL PADDOCK, M. S., | HORTICULTURIST |
| B. C. BUFFUM, M. S., | AGRICULTURIST |
| R. E. TRIMBLE, B. S., | ASSISTANT IRRIGATION ENGINEER |
| E. D. BALL, M. S, | ASSISTANT ENTOMOLOGIST |
| * E. S. G. TITUS, B. S., | ACTING ASSISTANT ENTOMOLOGIST |
| A, H. DANIELSON, B. S., | ASSISTANT AGRICULTURIST AND PHOTOGRAPHER |
| F. M. ROLFS, B. S., | ASSISTANT HORTICULTURIST |
| F. C. ALFORD, M. S., | ASSISTANT CHEMIST |
| EARL DOUGLASS, M. S., | ASSISTANT CHEMIST |

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### OFFICERS.

PRESIDENT BARTON O. AYLESWORTH, A. M., LL. D.

| | |
|---|---|
| L. G. CARPENTER, M. S., | DIRECTOR |
| A. M. HAWLEY, | SECRETARY |
| † W. R. HEADDEN, B. S., | STENOGRAPHER AND CLERK |
| A. D. MILLIGAN, | STENOGRAPHER AND CLERK |

* To June 1, 1901.
† To October 1, 1901.

THE EXPERIMENTAL PLATS.

# SECRETARY'S FINANCIAL REPORT OF THE COLORADO AGRICULTURAL EXPERIMENT STATION FOR FISCAL YEAR ENDING JUNE 30, 1901.

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| Dr. | U. S. Fund. | Special Fund. | Total. |
|---|---|---|---|
| From the Treasurer of the United States, as per act of Congress approved March 2, 1887 | $15,000.00 | | |
| Balance July 1, 1900 | | $ 317.47 | |
| Farm products | | 1,280.10 | |
| Miscellaneous | | 306.87 | $16,904.44 |
| By Salaries | $10,773.53 | $ 209.51 | $10,983.04 |
| Labor | 691.20 | 136.61 | 827.81 |
| Publications | 1,546.99 | 179.80 | 1,726.79 |
| Postage and Stationery | 335.17 | 217.17 | 552.34 |
| Freight and Express | 15.82 | | 15.82 |
| Heat, Light, Water, Power | 0 | 0 | 0 |
| Chemical Supplies | 6.43 | | 6.43 |
| Seeds, Plants, Sundrry Supplies | 169.42 | 4.90 | 174.32 |
| Fertilizers | 156.00 | | 156.00 |
| Feeding Stuffs | 10.60 | | 10.60 |
| Library | 37.74 | | 37.74 |
| Tools, Implements, Machinery | 19.15 | 14.50 | 33.65 |
| Furniture and Fixtures | 108.45 | 333.33 | 441.78 |
| Scientific Apparatus | 84.92 | 349,02 | 433.94 |
| Live Stock | 39.50 | | 39.50 |
| Traveling Expenses | 944.59 | 113.70 | 1,058.29 |
| Contingent Expenses | 10.00 | 47.50 | 57.50 |
| Building and Repairs | 50.49 | | 50.49 |
| Total | $15,000.00 | $1,606.04 | $16,606.04 |
| Balance June 30, 1901 | | 298.40 | 298.40 |
| | $15,000.00 | $1,904.44 | $16,904.44 |

A. M. HAWLEY,
Secretary.

# REPORT OF THE DIRECTOR.

*To The Executive Committee*:

Gentlemen: I have the honor to present the following report as Director of the Experiment Station for the present calendar year. This also includes the reports of progress of the different sections.

### FINANCES.

As the fiscal year ends June 30, it is more convenient to report the situation at that time. For the fiscal year ending June 30, 1901, the receipts from all sources amounted to $16,280.17. There was a balance of $317.47 brought forward from the previous fiscal year, and $298.40 carried forward, thus making the total expenditure $16,606.04. For the current fiscal year the estimate of receipts is larger, due to the funds received from sales of property at substations.

### PUBLICATIONS.

Since the 1st of December, 1900, we have issued eight bulletins, one of which was in two editions. Two bulletins are now in press. We also issued six press bulletins and twenty-six special river bulletins, and two extracts from the regular report. The editions of the regular bulletins have had to be increased from 6,000 to 8,500. This means a considerable additional expense. The total number of copies of the report issued during the year was 1,500; and of the bulletins 51,000; of the press bulletins 22,000; of the river bulletins 10,000, making a total of over 85,000 copies, which have been distributed during the year. The number of pages thus distributed is over 1,500,000. In the number of pages and in the number of publications issued during the year we shall equal almost any station in the United States. 100 volumes of the publications of last year were bound with cloth covers for the use of offices and libraries and places where it was desirable to have bound copies. This has been a very desirable and acceptable edition.

Progress has been made during the year in binding the bulletins received from other Stations. This step has been necessary in order to preserve records which are very important in Station work. A great deal of time has been taken in attempting to complete our files of bulletins. We still lack some bulletins from a number of states, but the sets are gradually being completed, and as fast as this is being done, they are bound.

During the year the substations and the problems arising from them have taken an undue amount of time. Their affairs are now, however, more simplified than before, and it is hoped that in the future they will be in better condition. It is evident that in order that the substations may be an integral part of the main Station, so that the work done there may be of service in the larger plans of the Station, that the substations need. be in closer touch with the main Station, and that there should be closer supervision. I will give a more complete statement of the affairs of the substations before closing this report.

### THE PROBLEMS OF THE STATE.

This State is so large and with such a variety of conditions that the number of problems pressing for solution is greater than we can take up. When we recall that Colorado is as large as the states of New York, Maine, Vermont, New Hampshire, Massachusetts and Rhode Island together, and that in this area equal to Colorado, the six stations supported from the Hatch fund have not only been kept busy with the problems of this equal area, but the demand for their work has required several State Stations in addition, and that these States have appropriated over $100,000 in addition to the $90,000 from the government, it becomes evident that we cannot take up all the questions which arise in the area when we have an income of not over one-thirteenth as much.

There are so many problems peculiar to this State in the solution of which we can obtain little help from the investigations of other States, that our policy should be to refrain from lines where their investigations may apply to our conditions. There is even then far more work than we can take up. The temptation has been to take up problems and not carry them through to completion.

The development of the sugar beet industry is a gratifying result of the work of this Station, and of the other Stations in the United States as well as the Department of Agriculture. It is an industry of great promise, the rise of which is purely one of scientific investigation.

The work of the Station has proceeded pleasantly, and while we can realize defects, yet we can see a material improvement. In considering the conditions which may increase the efficiency of the Station work, we are first impressed with the multiplicity of duties devolving upon the Station workers. For the best results in scientific work, not only a peculiar aptitude is required, but the work can not be well performed if the worker's time is constantly interrupted, or if work is approached when one is mentally fagged. The higher class of scientific investigation requires a fresh mind, a condition to be attained for only a few hours per day. The work of teaching is pleasant and profitable to most workers, and the greatest objection from the standpoint of the Station worker is that it breaks up the day. Even though the number of hours taken is not great, the day may be largely spoiled for investigation. From this standpoint, it would be better for the interests of the Station if the time of teaching on the part of the Station staff could be so arranged that some days of the week could be entirely free from such work, and given completely to investigation. This is one of the conditions which would probably increase the efficiency of our Station work. As it is, the work performed is apt to be far in advance of the published reports of the investigations. The preparation of bulletins and reports require in most cases considerable expenditure of consecutive time.

In the increase of usefulness of the Station, the development of our publications is also one of importance, and also the distribution of the bulletins. It is not only probable, but is known to be true, that a large portion of our bulletins reach people who do not make use of them. This is a condition which we hope to improve by making a classification of the names on the mailing list. At the same time, a classified mailing list is not a safe guide, because it so frequently happens that the very person who is the most interested in the bulletin is one whose line of interest is not indicated by his occupation. At present it would seem that without largely increasing the cost of distribution we must needs expect that a large part of the bulletins will not be used. We cannot expect to have results much greater than skilled advertisers who expect that only one person out of a great many will read their advertisements.

Another means of rendering our bulletins available to the public is through the medium of the Farmers' Institutes. These are good and form a supplement to the bulletin and printed reports; and are of value to the worker also, as they bring him in contact with the problems of the farmer in different portions of the country.

## SUBSTATIONS.

During the past fiscal year only one substation has been in operation, that at Rockyford. In consequence of the refusal of the Department of Agriculture to countenance further expenditures, none has been made on the Stations at Cheyenne Wells, though investigations have been continued on the problems of the Plains.

## THE DIVIDE SUBSTATION.

Since the last annual meeting of the Board, the affairs of the Divide Substation have been closed by the authorization of the Board. Our interests have been sold to Mr. W. A. Diebold for the sum of $650, of which $250 has already been paid. The remaining $400 bears interest at 6 per cent. per annum, and is to be paid within two years. The deed has been made out and is held in escrow by the First National Bank, of Colorado Springs.

### THE SAN LUIS VALLEY SUBSTATION.

During the past year the affairs of this substation have been put on a better basis. The State Land Board had called for the return of the land to the State. It has been deeded back to the State Land Board by the authorization of the State Board of Agriculture. Prior to that time, our interests in the land had been sold to Mr. Oscar S. Wyland for $1,900, to be paid in four payments; the first for $400, in 1901; the second for $500 in 1902; the third for $500 in 1903; the fourth for $500 in 1904.

Mr. Wyland already had possession of the place and had crops in the ground in consequence of a previous understanding and we felt under obligations to treat with him. The bargain, howevver, was very advantageous to us. The first note is secured by a chattel mortgage on the crops and hogs. The other notes are secured by lease from the State Land Board, which is assigned to us.

The personal property remaining at the Station was of little value. This was left with Mr. Wyland, and is a part of the improvements which he purchased.

In addition to this, there was some personal property in the possession of P. A. Amiss, consisting of one team of horses, one wagon, and other property of which we could obtain no clear description and which might be difficult to identify. This property was sold to Mr. Amiss for $100 in cash. The money has been received and the transaction closed.

### THE PLAINS SUBSTATION.

The Department of Agriculture having notified us that no further expenditure from the Hatch fund could be made at this Station, the plan of work has been along such lines as to cause no necessity for expenditure in connection with the Station itself. Mr. Payne has remained in charge, but with the title of field agent, instead of superintendent of the Station. The duty of the field agent is to investigate conditions in Eastern Colorado, and study the Plains with a view of finding out what has been, and is being done in agriculture, that may give promise of success. During the summer his trips have extended from the Arkansas river on the south, and nearly to the Platte on the north, and has covered a large portion of the country between these two points. He has lived in the house at the Station and made it his headquarters. The land at the Station was leased to J. W. Adams, who formerly worked at the Station, and as a condition of the lease, he was to take care of the fruit trees which were planted near the house. The lease has been quite satisfactory and the place well cared for. The crop of sorghum which was grown produced a number of tons of forage.

As there is nothing to be done at the substation during the winter months, Mr. Payne has moved to Fort Collins, and the house has been rented for $4 per month, during the winter to a school teacher in Cheyenne Wells. The understanding is, however, that the Plains investigations shall be continued as during the past season.

As the situation now is at Cheyenne Wells, the buildings and improvements belong to the Experiment Station, but the title of the land is conditional. These buildings were partly put up by money from the Internal Improvement fund and from local sources. The buildings are good but the demand for them at that place is small. Cheyenne Wells derives its principal importance as the end of a division for freight trains, and as an eating point on the railroad. It is likely that dining cars will soon be substituted, in fact an order was promulgated that dining cars should be run from October 10. This action, however, has been delayed. It is only a question of time until the importance of the place becomes less, and the value of our improvements will be correspondingly decreased.

There is no doubt under our title regarding our rights to the improvements, if it becomes necessary to withdraw. As it now is, we cannot spend any of the Hatch fund, and there has been no provision to expend any of the other funds of the Board for that purpose. We shall get very little for the improvements when it becomes necessary to sell. The sum received will be far less than the amount which has been spent for them.

### THE ARKANSAS VALLEY SUBSTATION.

In the case of the Arkansas Valley Substation, a large part of the land was leased to tenants for cash or for a portion of the crop. About twenty-five acres are retained under the supervision of the Station, an amount which could be attended to by the Superintendent and one man.

The total amount expended for the fiscal year ending June 30, 1901, was $1,726.43; the net receipts for the same time were $1,148.46, making a net cost of $577.97.

By action of the Board of Agriculture at the meeting in July and in accordance with a letter from Dr. A. C. True, it was decided to return to the State Land Board 160 of the 200 acres which had been put at our disposal for experimental purposes. With that authorization, the deed was transferred to the State Land Board. At the same time the Station also had twenty-four shares of stock in the Rockyford ditch; one of these shares had been issued by mistake and the Board authorized its return to the Secretary of the Company. It had not been absolutely settled at that time whether the stock was to be returned to the donors in case of the abandonment of the Station or not. The records of the Board and especially those conditions upon which the Station was located at Rockyford would seem to indicate that it was an absolute gift.

The Board authorized the sale of the thirteen shares upon the condition that the purchaser should return the stock at any time of tender of the amount which he had paid. Since that time, the original donors of the stock have made claim that the stock by right belongs to them; that they gave it with the understanding that it was to be returned to them in case the Station was abandoned. The stock was given by individuals who gave from one to two or three or four shares each, and from the evidence now available, it appears the committee soliciting this stock made such representation to the donors. On the other hand, nothing has been found which would show that this was not one condition required by the Board; in fact, the records of the time would seem to indicate that the stock was to be in fee simple on the location of the Station. These donors will present their claims and perhaps be represented by a committee at this meeting of the Board. They will present such evidence as they may have which throws light on their arrangements with the Board at that time.

The improvements on the portion of the place which was relinquished were sold to G. W. Swink for $1,500. Mr. Swink had the original lease on this tract of land and relinquished it for the use of the Experiment Station in the year 1888. He made payment of one-fourth in cash and the remainder in approved notes bearing six per cent. interest. He has arranged that additional security should be given by the retention of the water stock for which he had bargained, until the whole transaction was completed. If it should be deemed best to return the stock to the original donors, the question will arise as to whether additional security should be given.

In a letter dated June 1, Dr. A. C. True, Director of the Office of Experiment Stations, having general supervision of the Hatch fund, wrote definitely that he must insist more strongly that the use of the Hatch fund for substations should be discontinued. This seemed to be a prohibition of the use of the Hatch fund for these purposes. This being the case, the question of the policy to be adopted toward the Substation at Rockyford arises. The Hatch fund, which has been the fund that has maintained this Substation, and during the time since its establishment, something like a total expenditure of $33,190.50 has been made. There have been receipts of $11,393.09, making a cost of $21,799.41. The net cost of the Experiment Station has never been so small as during the past two years, when it amounted to less than $1,000 each year. In the years previous to that time when the ground was under the charge of the Superintendent, the cost one year was as low as $1,100 ($1,070.80), and as high as $2,900 ($2,890.66.)

There would seem to be three courses open to us:

1. To discontinue the work entirely.
2. To continue as a garden tract in an experimental way, as it was during the past year. This would require the maintenance of a man, a team and tools; a total expense including the salary of the Superintendent of not far from $1,800.
3. The use of the place only as a headquarters, retaining the improvements, house and grounds adjacent to it for the use of the Field Agent, permitting him to live there, and leasing the balance of the forty acres in such a way that we would not be responsible for any of the expense.

Under the ruling of the Department, it is still a question as to what extent it would sanction payment, except temporarily, of the Superintendent of the Station. In an official ruling some years since, the Department clearly stated its conception of the use of the Hatch fund. The Department recognizes the desirability of investigation in different portions of the State. It recognizes this as a proper charge upon the Hatch fund, where the work is of an experimental nature. Under this arrangement, it would seem possible for us to take up most of the investigations, or at least, part of them.

The work of the various sections is shown in the reports here appended.

Respectfully submitted,
L. G. CARPENTER,
Director.

# REPORT OF THE ENTOMOLOGIST.

I have the honor to submit herewith the annual report of the entomological section of the Agricultural Experiment Station for the year 1901.

## WORK WITH THE CODLING MOTH.

This insect occasions such heavy losses to fruit growers of Colorado each year that a considerable time has been devoted to a study of its habits and remedies. Much of the information gained had already been *published in one place or another but comparatively little has appeared in bulletins or reports of the Experiment Station. I have therefore thought it desirable to summarize the more important observations and conclusions in this report. They are as follows:

### *Life History.*

*Eggs* of the spring brood begin to be deposited upon fruit and leaves when summer apples, like the Duchess, are about three-fourths of an inch in diameter. The last eggs of the brood are not deposited until late in July. The late moths of this brood have continued to appear in our breeding cages in cellars, to July 24.

The eggs, according to our observations, have been almost entirely upon the smooth surface of the apples, a small proportion, perhaps 10 per cent. have been found upon the leaves. Very few (3 or 4 per cent.) of the eggs under observation have failed to hatch, but there has been apparently a large mortality among the young worms. The time for eggs to hatch in the laboratory has varied between 6 and 8 days, with an average time of about 7 days.

The earliest we have found eggs on the apples at Fort Collins was June 9. Last year the first eggs were found June 19; the eggs of the first brood became most abundant about July 3, and summer eggs were most scarce about July 21. On July 27 an increase due to the eggs of the second brood was noticeable. Second-brood eggs were most abundant about August 12.

*Larvae* of the first brood began leaving the apples about Fort Collins in the spring of 1901, July 1; they were coming down most rapidly about July 21. By August 15 the larvae were coming in very small numbers and some of them were of the second brood as was shown in the fact that they began at about this date to live over till spring before pupating. The larvae of the second brood were most numerous under bands about September 10.

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*Reports of Colorado State Board of Hort. for 1897, 1898, 1900, 1901 and Bull. 31, N. S., U. S. Dept. of Agr., Div. of Ent., p. 5.

The time required for larvae of the first brood to develop varied between 12 and 24 days with an average time of 19 days.

The time spent spinning and pupating varied between 1 and 19 days with an average of 5.6 days. The greatest number pupated on the 4th day.

The time spent in the chrysalis by the summer brood varied between 10 to 21 days and the average time was 14 days.

For the entire cocoon stage the time varied between 12 and 29 days with an average of 20 days.

The time required to pass through these transformations at Fort Collins is no greater, according to our records, than at Rockyford, Canon City and Grand Junction where the summer temperature ranges considerably higher. The time spent in the complete summer life cycle has varied greatly but the average time has been almost exactly seven weeks.

Practically all the larvae taken at Grand Junction after August 10, and at Rockyford and Canon City after August 15, and at Fort Collins after August 20 live over till next spring before pupating. Occasional belated individuals are exceptions to the rule.

*Moths* from warm winter quarters may appear very early. Up to the time the orchards are in full bloom, we have found only about 10 per cent. of the moths hatched. At about this time they begin to appear rapidly.

The latest we have been able to rear moths of the second brood at Fort Collins has been September 16. The latest reported from other parts of the State by those who have assisted in the work have been as follows: Grand Junction, Sept. 12 (Silmon Smith); Canon City, Sept. 10 (R. J. Peare); Rockyford, Sept. 15 (H. H. Griffin); Palisade, Sept. 22 (C. H. Potter.)

### *Miscellaneous Notes on Habits.*

While the second brood are generally thought to enter largely at the side of the apples because of the many worm holes seen there, our counts have so far indicated that 80 per cent. enter at the blossom end. Very many, however, enter by a very small hole, leaving no outside evidence, and then burrow to the surface on the side of the apple and keep the latter burrow open but not the entrance at the blossom.

Spring migration of the larvae is usually very light, but in a few instances they have come to bands in considerable numbers in certain orchards about Grand Junction during March and April.

Bands removed from a tree at 6 o'clock each evening and 7:30 each morning gave 414 larvae, 353 or 85 per cent. of which came to the band during the night period and 61 or 15 per cent. came during the day.

By the use of bands we have taken from 17 per cent. to over 60 per cent. of the larvae on a tree as indicated by the number of wormy apples. The largest number of larvae from one band during the season is 1481. The tree was in a lawn and isolated.

Gathering apples daily from the ground gave us 16 per cent. of the worms from Duchess apples and 3.5 per cent. of the worms from Ben Davis trees as indicated by the number of wormy apples.

The saving of wormy fruit as the result of spraying twice with Paris green has varied in our experiment between 25 per cent. and over 90 per cent. The 25 per cent. saving was upon Duchess trees when the calyces of the apples had nearly all closed before the first application. The ninety odd per cent. was upon winter varieties.

### LONG-TONGUED HONEY-BEES.

Bees from different parts of the United States were examined for the purpose of determining the range in length of the tongue of the honey bee. A progress *report on the work was made at the Annual Meeting of the Colorado State Bee-keepers' Association in Denver, November, 1901, and the work is not yet fully completed.

I have found that thrusting a bee into boiling water kills it in the best way to leave the tongue extensible for study.

I have been unable, so far, to find any evidence of a long-tongued strain of Italian bees, though several advertisers of "long-tongued" or "red clover" bees sent bees for examination. Tongues of the German or black bee have ranged between 23.5 and 25 hundredths of an inch; tongues of Carneolans between 25.5 and 26 hundredths of an inch; tongues of Italians between 24.5 and 26 hundredths of an inch, and tongues of Cyprians between 25 and 27 hundredths of an inch. Tongues of *Apis dorsata* preserved in alcohol measured between 25 and 26 hundredths of an inch. Tongues of bumblebees measured in comparison varied between 43 and 58 hundredths of an inch in length.

In all cases the distance from the base of the sub-mentum to the tip of the ligula has been taken as the tongue-length.

### SUGAR BEET INSECTS.

Considerable attention has been given the past year to observations upon sugar beet insects on account of the importance which the sugar beet crop is assuming in Colorado.

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*The paper is printed in full in Am. Bee Journal, Dec. 12, 1901, and in Bee-Keeper's Review, Jan., 1902.

The beet army-worm *(Laphygma flavimaculata)* was not seriously abundant but attracted some attention in the lower Arkansas Valley over limited areas. Where the arsenites were used promptly they were successful in killing the worms. Mr. H. H. Griffin, Field Agent of the Experiment Station, reports that he found best success from the use of strong mixtures. He recommends using Paris green in the proportion of a pound to 50 gallons of water.

*Nysius minutus,* one of the false chinch bugs, was unusually abundant in the State last summer attacking a variety of plants upon both the east and west slopes of the mountains. One of its favorite plants is the beet. In places, many young plants were killed by them and Mr. Griffin and others at Rockyford state that they attacked mother beets that were being grown for seed so badly in places as to seriously injure the crop. Prominent among the cultivated plants attacked by this bug about Fort Collins last summer were beets, radishes, cauliflower and strawberries. The weeds most attacked were wild mustard, a tumble-weed *(Monolepis nuttallii),* yellow dock, lamb's quarter and Helianthus (sunflower). Many others were attacked to some extent.

Kerosene emulsion, whale-oil soap and Buhack were used in varying strengths for its destruction but almost without effect.

The accompanying cut shows the bugs about life-size on the leaves of yellow dock. (Fig. 1, Plate I).

The beet-louse *(Pemphigus betæ Doane),* was received upon the roots of beets from the vicinity of Rockyford and were sent by Mr. H. H. Griffin. The lice were found when the beets were harvested. The lice were sent as mealy-bugs because of the powdery covering to the body. Beets having the lice upon them were said to be spongy and of poor quality. Mr. Griffin thinks they occurred in several fields near Rockyford last year. It seems probable that this louse must occur upon the roots of some native plant in that vicinity and that it is transferring its attention to the beets.

### MISCELLANEOUS NOTES.

Howard's Scale *(Aspidiotus howardi).* This is a near relative of the San Jose scale and was discovered by the writer some years ago on plum and pear trees in Canon City, Colo. The scale seems to have been the cause of the death of a few plum and prune trees near Canon City in one small orchard where it was first found and it still occurs in small numbers in that locality. I have not known of its occurring outside of Canon City until the past summer when the inspector of Delta county, Mr. H. E. Mathews, sent me specimens of the insect and later took me to an orchard where pears and plums, particularly the former, were badly attacked by it.

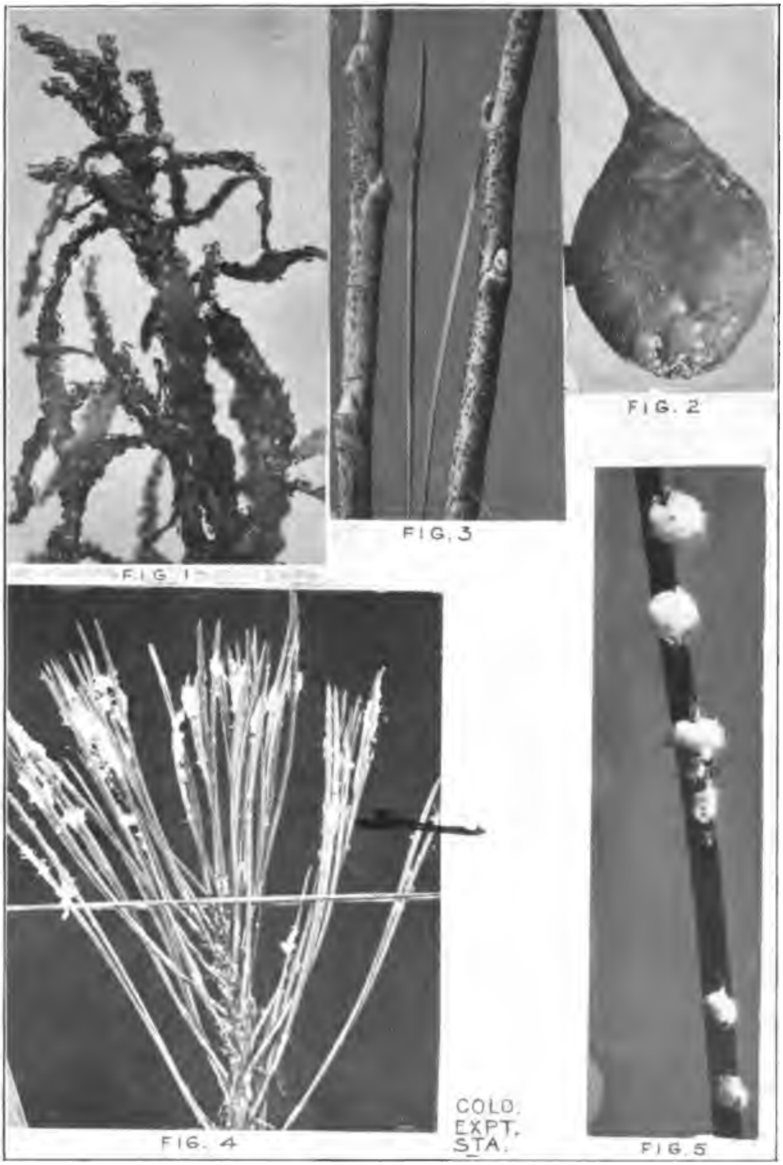

PLATE I.

Fig. 1. False chinch-bug (Nysius minutus) on leaves of yellow dock, nearly life-size. From photo by author.

Fig. 2. A young Bartlett pear, life-size, showing both young and adult scales of Aspidiotus howardi. The young scales are white. From photo by author.

Fig. 3. Two apple twigs showing eggs of apple louse, Aphis mali, and between these twigs two needles of Pinus ponderosa showing eggs of a species of Lachnus. Photo by author.

Fig. 4. A bunch of pine needles, natural size, showing the white waxy secretions of the lice. From photo by author.

Fig. 5. A pine needle much enlarged showing the masses of white waxy secretion covering the lice and their eggs. At (a) the eggs may be seen protruding from under the secretion. From photo by author.

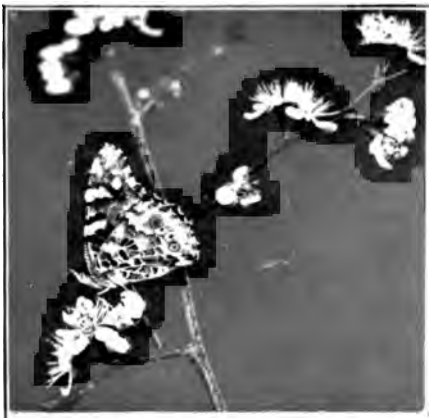

FIG. 6

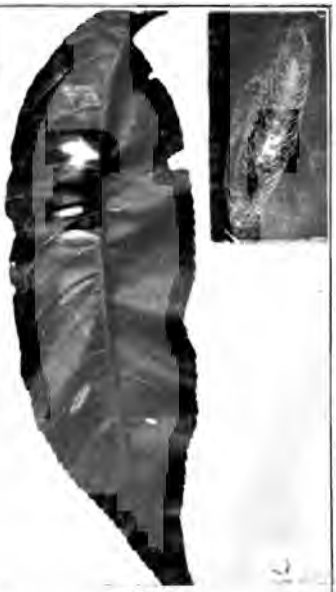

FIG. 7

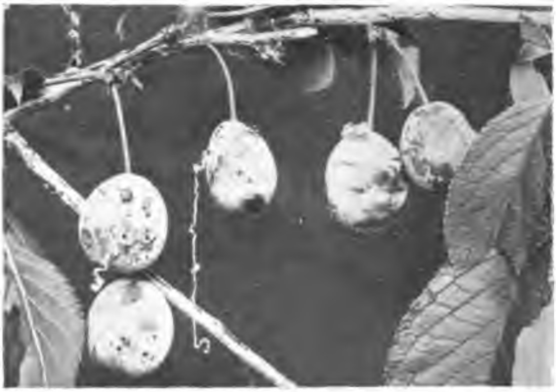

FIG. 8

COLO. EXPT. STA.

PLATE II.

*Fig. 6. The thistle butterfly, Pyrames cardui, at plum blossoms; nearly life-size. From photo by author.

Fig. 7. A, peach leaf, life-size, showing cocoons of Plutella cruciferarum; B, one of the cocoons much enlarged showing its frail gauzy structure. From photos by the author.

Fig. 8. Plums, life-size, showing the punctures and gummy exudations caused by the plum gouger, Coccotorus prunicida. The black specks on the plums represent the punctures which are made either for the purpose of taking food or egg-laying. Photo by author.

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*A halftone from the same photograph was given in Agricola Aridus, Vol. 1, No. 3, p. 7.

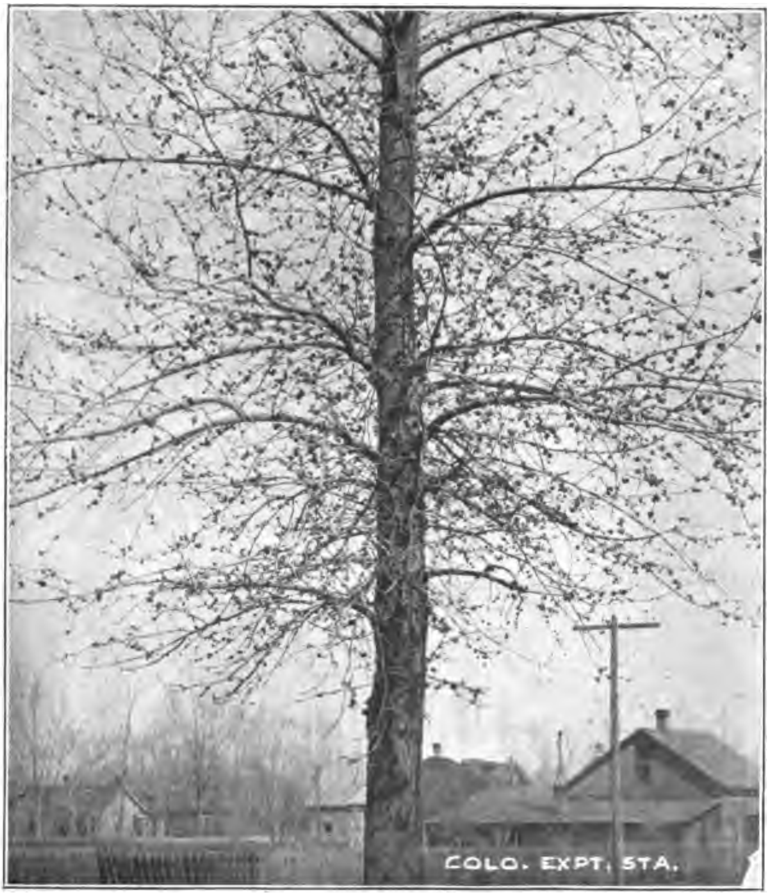

Fig. 9. PLATE III.

Fig. 9. A cottonwood tree showing galls of Phytoptus mite on twigs. From photo by author.

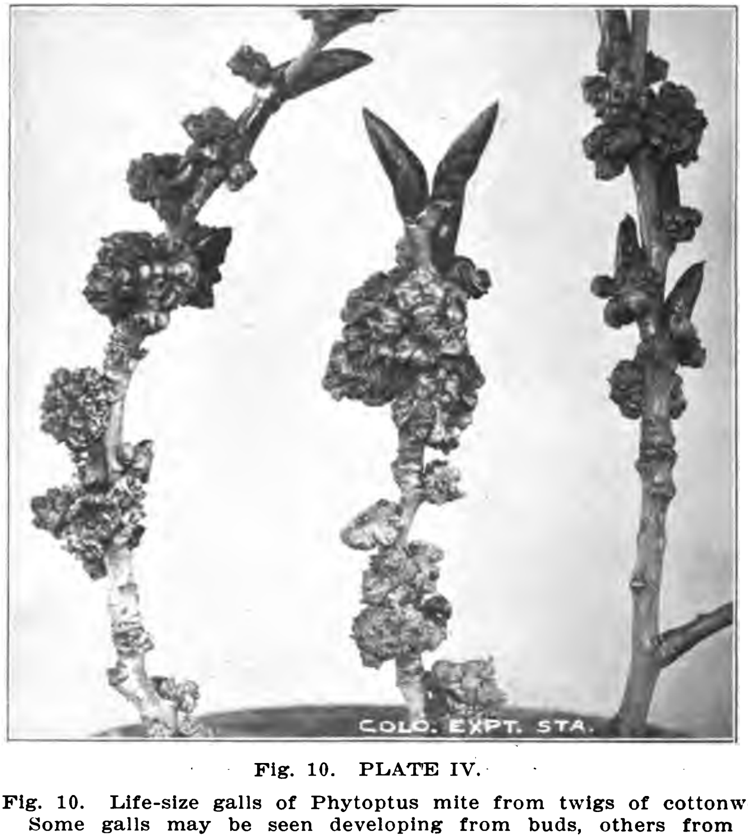

Fig. 10. PLATE IV.

Fig. 10. Life-size galls of Phytoptus mite from twigs of cottonwood tree. Some galls may be seen developing from buds, others from the smooth bark of the twigs. From photo by author.

The orchard was examined June 12, at which time the young lice were just beginning to hatch. Pears containing lice were brought to the Station and the young continued to appear till August 20. The newly hatched lice are of the usual yellow color. They locate mostly about the blossom end of the fruit and the first scales are pure white. The older scales become darker and are usually sunken into the fruit. Sometimes there is a reddish discoloration about the scale. On raising a female scale it was often possible to find two or three lice and no eggs, but occasionally an egg or two or perhaps as many as three or four were also present. More often there were no eggs at all. So the lice hatch almost immediately upon the laying of the egg or, perhaps they as often hatch before the egg is laid.

The accompanying cut (Fig. 2) shows the scales, life-size, upon a pear.

The Apple Louse *(Aphis mali)*, continues to be a common and often very abundant pest upon the foliage of apple and pear trees after the middle of July or the first of August. During winter and early spring the black shining eggs are often seen in great numbers upon apple twigs. They are shown life-size, in Fig. 3. We have been unable to hatch these eggs when brought into the laboratory. Whether or not they hatch late in the spring upon the trees we have not certainly determined.

Woolly lice on spruce and pine. Two species (possibly one) of Chermes attack the leaves of spruce and pine in northern Colorado. The lice are very dark green in color having the appearance of black specks to the unaided eye. They arrange themselves along the leaves or needles and the females secrete large quantities of white waxy material to cover their bodies and also the clusters of amber colored eggs which they deposit in compact mass behind them. Each egg is attached by a thread. (See Figs. 4 and 5).

I have found kerosene emulsion or whale-oil soap of the ordinary strengths very effectual in killing these lice and their eggs.

The Thistle Butterfly *(Pyrames cardui)* was unusually abundant in many parts of Colorado last summer and attracted considerable attention from fruit growers, who were afraid it might be some insect injurious to fruit. The butterflies were abundant at blossoms of plum, cherry, apple and other fruit trees on both the eastern and western slopes. This insect is probably more beneficial than injurious as the larvae feed chiefly upon the leaves of thistles and other composite weeds and the butterflies assist in the fertilization of fruit blossoms.

The accompanying cut (Fig. 6, Plate II) shows a butterfly at plum blossoms.

The Cabbage Plutella *(Plutella cruciferarum)*. What seems to be a very unusual habit of this insect occurred in Colorado last summer. Mr. H. E. Mathews, horticultural inspector for Delta county, sent me a quantity of peach leaves partly eaten and having attached to them large numbers of little white cocoons. Mr. Mathews stated that a portion of a young peach orchard had been very badly defoliated by this insect. In a few days the moths of the above named insect appeared from the cocoons and I was greatly surprised to find this eater of cruciferous plants attacking the peach. On visiting Mr. Mathews later I learned the particulars of the case which are as follows: The year previous a large amount of wild mustard had been allowed to grow in the orchard as a weed. Last summer clean cultivation was practiced and the moths of this insect, not finding the mustard upon which to deposit their eggs, turned to the only available plants, the peach trees. The accompanying cut shows the cocoons life-size, on a peach leaf and also a cocoon enlarged so as to show its gauzy structure. (Fig. 7, Plate II).

The Plum Gouger *(Coccotorus prunicida)* is abundant every year on the eastern slope where it is a very serious pest injuring the fruit of the red or Americana plums. The punctured plums are deformed, and gummy exhudations appear on the wounds made by the beetle for the purpose of egg-laying or taking food. The wounds made by the beetle and the exhudations are shown in Fig. 8.

If all growers of plums in a considerable area would agree on a year when they would all remove every stung plum from their trees between the middle and the last of July, they could in this manner almost exterminate the pest for a number of years.

I have found no signs of this insect on the west slope and it does no appreciable harm to European varieties of the plum.

*Phytoptus Gall on Cottonwoods.* Since coming to Colorado, some ten years ago, I have noticed the gradual increase in numbers of a small gall upon the twigs of the cottonwood. While the gall occurs generally over the State, it seems most abundant in the northern portion. Many cottonwoods in Fort Collins have these galls upon nearly every twig. They may form upon buds or upon the smooth bark as shown in the accompanying illustration. It is not uncommon to find trees as badly infested as the one shown in Fig. 9. Fig. 10 shows the galls life-size.

It will be difficult to apply remedies as the mites live over winter in recesses in the galls. The mites are reddish in color during winter and if galls are cut into at this season the mites may be found in great numbers in clusters. The galls do not have the effect to kill the trees as yet, and few limbs seem to have died from their attacks but they cause an unsightly appearance of the trees when the foliage is off.

C. P. GILLETTE.

# REPORT OF THE CHEMICAL SECTION.

*To The Director of the Experiment Station*:

I herewith transmit my annual report regarding the work carried on by this Section of the Experiment Station.

No new work has been undertaken. The work set forth in the outline discussed at the January meeting of the Station Council has been prosecuted to the exclusion of all other work, no deviation having been made from the original plan.

There is at the present time a large mass of results which have not yet been published, but which are now in the course of preparation for publication.

The digestion experiments mentioned in the outline as having been at that time, namely, in January, far advanced, have had to be repeated and will probably be completed early in the fall, as will also the work on beeswax, which will be carried on by Mr. F. C. Alford.

There are no new needs of this Section which I shall present at the present time, as I believe you are fully conversant with the status of the section and its equipment.

Respectfully submitted,
WM. P. HEADDEN.

# REPORT OF THE AGRICULTURIST.

The Experiment Station work in the Department of Agriculture has been somewhat varied during the year. Something has been done on each of the lines of work as planned at the beginning of the season of 1901. One bulletin, No. 66, on Tuberculosis, jointly written with the Veterinarian, Dr. G. H. Glover, has been published, and considerable material is on hand for other Station bulletins. It being the first year of the writer's work in this Station we have preferred to corroborate many of the notes before publishing them. Material is on hand for a bulletin on feeding Belgian hares, and some interesting results were obtained in feeding sheep and swine.

A large amount of data is accumulating from investigations with wheat and oats, especially with that part of the work which is being carried on at Monte Vista and at the College to compare the raising of grain at high and low altitudes. Published with the report is an account of our first year's work with macaroni wheats. We believe this variety of wheat will be quite valuable, especially in those portions of the State where irrigation water is either very scarce or wanting, and agriculture is carried on under scanty supply of rainfall. A number of varieties of macaroni wheat have been introduced from Russia by the U. S. Department of Agriculture which are being grown here in co-operation with the Department. Some of these varieties were collected on the high, dry steppes of Russia where they were raised without irrigation.

One of the most important lines of investigation which we have attempted is the work with grasses in co-operation with the Division of Agrostology. We publish herewith a detailed report of what was done the first year with a large number of varieties both in the grass garden and in a field which could be pastured. There is so much demand for information in regard to grasses which will either improve our ranges or be suitable for the making of pastures which can be irrigated, that we consider this line of work very important, and desire to give it much attention during the coming season.

The crop plats established last year gave some interesting results. Wheat which had been grown for a number of years at altitudes of 7,000 feet, shows a remarkable deterioration when planted here. The result was the same with a large number of varieties and it is interesting to know whether grain raised at high altitudes is always apt to deteriorate sufficiently to produce very small crops when grown at low altitudes. On the other hand varieties of wheat obtained from Wm. Farrar, the great breeder of new wheats in Australia, did remarkably well, ripening a week or more earlier than the varieties which had been grown at home.

Two new brewing barleys, seed of which was furnished us by the U. S. Department, produced large crops here last season, and Russian spelt, so-called, really a variety of emmer was grown in sufficient quantity to supply grain for some feeding experiments which are now being carried on.

Although so much has been done by the Station with sugar beets during the past twelve years, we are now face to face with this new industry and should like to keep in touch with the commercial side of the question so far as our experimental work will be of value to farmers who are raising beets for the factories. The past season we raised sugar beets from which are to be selected mother beets for the production of seed. There is much demand also for information in regard to sugar beets for stock feed, so it is expected that beets will figure in the rations we adopt for experimental work in stock feeding, until we are fairly well acquainted with their effect when given in addition to other foods. A field experiment on the College farm was carried out with potatoes, the results of which are reported herewith in detail.

The Director distributed a large number of samples of sugar beet seed to farmers last spring. This seed was furnished by the U. S. Department for distribution. Very few of the farmers have reported the results obtained with the beets raised from this seed.

In addition to our work at home with feeding and cropping we have been able to accumulate some information from outside sources which will be of considerable value. Col. J. A. Lockhart, of Rockyford, who is feeding about 3,700 head of cattle, and is using beet pulp and beet molasses in great quantities, has agreed to furnish us his data for publication. The records are being kept in such a way that this material will be of great value. We visited Rockyford on two occasions and have obtained some photographs of the feeding plant and of the cattle which are being fed for market.

We have taken a series of photographs in many of the experiments carried out and consider them a very valuable part of our Station records as well as serving a most useful purpose for illustrating when we have data of sufficient value for publication.

My Experiment Station Assistant, Mr. A. H. Danielson, is thoroughly efficient. He has made his records very accurate and valuable, and his work in photography is of such a character that it is almost indispensable. Mr. Danielson has furnished the detailed reports of experiments with wheats, grasses and potatoes published herewith.

While not an employe of the Station, Mr. C. J. Griffith, who is assisting with the live stock work, is also a careful investigator and through his efforts we are able to publish material of value with regard to feeding live stock, and have accumulated data which will be useful for Station publications in the future.

### FIELD EXPERIMENT WITH POTATOES.

In recent years it has not been possible to raise remunerative crops of potatoes in the vicinity of Fort Collins, and we carried on a field experiment to throw light on the difficulty if possible. While this experiment has been under way the Horticultural Section has also been working on the problem, and their discovery of the effects of a new disease on potatoes indicates, we believe definitely, the cause of our potato failures. It will probably not be advisable for us to continue the field experiments until such time as the Professor of Horticulture and his assistants have completed their work. Their investigations indicate that our soils have become so full of the fungus that causes the trouble, that it will be necessary to discover some general treatment which will destroy the disease producing spores, or to grow varieties of potatoes which will resist their attacks, or be immune.

Our field trial of last season is of interest, however, as it indicates that different varieties are affected in different degree. One of the objects of the experiment was defeated by accidentally getting the potatoes for seed which we had obtained from different localities mixed. We wished to compare seed raised at an altitude of about 9,000 feet in the mountains with seed of the same variety grown on the plains, but the two lots were not kept separate before planting so we are unable to report this comparison.

We purchased red and white potatoes in the market. The reds were probably Early Rose, and the white ones Mammoth Pearl, though the dealers could not give us the variety names. These were divided into separate lots. A part were treated and a part planted without treating, and parts were planted with and without fertilizers. The treatments given were with corrosive sublimate and formalin for scab, and the fertilizers used were raw bone meal and nitrate of soda. None of the potatoes produced large yields, but the red variety gave much better yields under the different treatments than was obtained with the white variety. The largest yield was 49¼ sacks per acre of marketable tubers, or a little less than 72½ sacks of large and small tubers.

The yields vary somewhat but it cannot be said that the fertilizers produced any increase. The treatment of seed with corrosive sublimate seemed to give a slight increase in yield of marketable potatoes, though the difference is small. The results of the experiment are given in the following table. The potatoes were planted late, June 17, and harvested October 14. Lot No. 13 in the table was selected as free from disease. Lot No. 14 was affected with a dry rot (Fusarium) and was not treated. Lot No. 15 was affected seed with the injurious fungus (Rhizoctonia) but not treated. Lot No. 16 was affected seed treated with corrosive sublimate, and Lot No. 17 was affected seed treated with formalin.

It will be noted that the selected clean seed not treated, gave the largest yield of marketable potatoes. The diseased seed produced a poor stand of potatoes, or rather, many of the plants died from the disease after they came up, cutting down the yield.

| Lot No. | Pounds Per Acre Planted | Variety Treatment Corrosive Sublimate | Pounds Fertilizer Per Acre | Marketable Per Acre | Not Marketable Per Acre | Total Per Acre | Weight of 10 Largest Pounds | REMARKS |
|---|---|---|---|---|---|---|---|---|
| 1 | 932 | Red, Not Treated | None | 2381 | 3075 | 5456 | 6.3 | Decidedly Scabby |
| 2 | 1207 | Red, Not Treated | 761 Bone Meal | 2520 | 4360 | 6880 | 6.1 | 36% Scabby, balance free |
| 3 | 941 | Red, Not Treated | 286 Nitrate of Soda | 2130 | 3700 | 5830 | 7.2 | Fair amount of scab |
| 4 | 832 | Red, Treated | None | 4525 | 2835 | 7360 | 8.0 | Free from scab |
| 5 | 762 | Red, Treated | 477 Bone Meal | 4925 | 2320 | 7245 | 7.25 | Free from scab |
| 6 | 754 | Red, Treated | 220 Nitrate of Soda | 4615 | 2115 | 6730 | 7.00 | Free from scab |
| 7 | 814 | White, Not Treated | None | 2440 | 2460 | 4900 | 6.2 | No Scab. Crackling of Skin |
| 8 | 786 | White, Not Treated | 599.3 Bone Meal | 2380 | 2190 | 4570 | 6.0 | Free from scab |
| 9 | 833 | White, Not Treated | 317 Nitrate of Soda | 2360 | 2170 | 4530 | 6.2 | Free from scab |
| 10 | 878 | White, Treated | None | 2320 | 1915 | 4235 | 5.75 | No scab. Few crackled |
| 11 | 867 | White, Treated | 771 Bone Meal | 2085 | 1965 | 4050 | 5.5 | Free from scab |
| 12 | 877 | White, Treated | 505 Nitrate of Soda | 2380 | 1690 | 4070 | 5.75 | Free from scab |

| Lot No. | Pounds Per Acre Planted |  | Marketable Per Acre | Not Marketable Per Acre | Total Per Acre | Weight of Largest 10 Pounds | REMARKS |
|---|---|---|---|---|---|---|---|
| 13 | 1019 | Clean Seed, Not Treated | 3733 | 2322 | 6055 | 10.5 | Free from scab. No crackling skin. Outer skin peeling off. |
| 14 | 641 | Not Treated | 1017 | 962 | 1979 | 6.00 | Poor stand. Small potatoes. |
| 15 | 1086 | Not Treated | 3666 | 2304 | 5970 | 9.00 | Free from scab. |
| 16 | 979 | Corrosive Sublimate | 2685 | 2549 | 5234 | 8.2 | Free from scab, or small traces. |
| 17 | 987 | Formulose | 2915 | 1889 | 4804 | 8.00 | No scab. Less smooth than preceding. |

PLATE V.

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### SHRINKAGE OF POTATOES.

Some of the red and white potatoes from the field experiment ere stored in a root cellar, careful weights being recorded to deermine the amount of shrinkage. There were two sacks of white otatoes and six sacks of a red variety placed on an old door hich was used as a platform to keep them dry. The white potoes were a late variety and having been planted so late, June 7, did not ripen. They were bruised and peeled badly from handling. They were weighed and placed in the cellar October 18, and were subsequently weighed December 14, and March 8 aproximately two, and four and one-half months after storing.

The following table gives the results. The lot numbers given in the first column correspond to the same numbers given in the table reporting the field experiment and are a key to the kind of seed, treatment and fertilizers used. It will be noted that the greatest loss of weight occured during the first two months, the average loss being 5.5 per cent. for that period, while it is only 7 per cent. for the whole time.

As would be expected the loss of the white potatoes which were green when harvested, was greater than the average. There is some variation in the shrinkage from the individual lots of red potatoes, but we would probably not be justified in stating that this difference is due to previous treatment of the seed from which the potatoes were grown, or to the fertilizers used.

SHRINKAGE OF POTATOES STORED IN SACKS.

| Lot No. | Variety | WEIGHT | | | | Per cent. Shrinkage in 4½ months |
|---|---|---|---|---|---|---|
| | | Oct. 18 lbs. | Dec. 14 lbs. | March 8 lbs. | Total Loss lbs. | |
| 18 | Red | 101 | 96 | 94.2 | 6.8 | 6.7 |
| 15 | " | 100 | 95.5 | 94 | 6.0 | 6.0 |
| 16 | " | 106 | 102 | 100.5 | 5.5 | 5.2 |
| 17 | " | 117 | 109 | 107. | 10.0 | 8.5 |
| 1 | " | 119 | 111.2 | 109.7 | 9.3 | 7.7 |
| 6 | " | 87 | 83. | 82 | 5.0 | 5.7 |
| 11 | White | 85.5 | 80.5 | 78.5 | 7.0 | 8.2 |
| 12 | " | 88.5 | 83 | 81.5 | 7.0 | 7.9 |
| Total.......... | | 804 | 759.2 | 747.4 | 56.6 | 7.0 |

### MACARONI WHEATS.

### A Brief Report of the Varieties as Tested at the Experiment Station, Fort Collins, Colorado, 1901.

Through the importation and distribution of macaroni wheats by the U. S. Department of Agriculture, considerable interest has been awakened in this class of grain. Macaroni wheats are considered drouth resistant varieties, and while there is objection in many parts of Colorado to any grain which produces beards, the macaroni varieties of wheat will undoubtedly take an important place in our agriculture, more especially so, perhaps, in the eastern part of the State where crops are raised without irrigation.

The varieties obtained from the U. S. Department were planted with a grain drill in plats 1-20 acre in size, using at the rate of 90 pounds of seed per acre. After harvest each plat was carefully measured and the yield per acre calculated. The stubble left on the field had an average height of 0.2 metres or 8 inches. The land used had been in grain the year before. The plats received one thorough irrigation June 26-27, and the precipitation for the growing season amounted to 10.53 inches, there being 7.47 inches in May, 2.35 inches in June and 0.71 inches in July. The weight per bushel of the grain harvested in nearly every case exceeded that of the seed planted. The table herewith gives the variety, the yield of straw and grain per acre, weight per bushel of that grown on the Station ground and of the seed received, and seasonal notes.

A report of these grains was made to M. A. Carlton, Cerealist of the U. S. Department of Agriculture. He writes as follows: "It is of particular interest to note how the weight of the grain which you have grown varies from the weight of the original seed, being in nearly every case greater than that of the original seed planted. The results as to yield per acre are considerably different in this case from what they have been in other states where trials have been made. In other cases the Kubanka has usually turned out the best, while in this case it stands only about fifth in the order of yield. The Gharnovka, however, which stands at the head in yield in this case is considered also a very good variety in south Russia."

The following additional notes not given in the table were taken of each variety:

No. 4277, Nicaragua. ("Triticum durum. This seed was obtained in Texas where the variety has been grown for a number of years. From its name it probably came originally from Nicaragua"). Was at about the right stage of maturity when harvested. Straw rather short. Grain of fair quality with somewhat smaller kernels than the others; small yield.

No. 5639, Kubanka ("Triticum durum, from Uralsk Territory, Russia. One of the best varieties of macaroni wheats in Russia"). This variety germinated and was above ground ahead of all others. A long strawed variety. The grain harvested was of less weight per bushel than the seed planted, lighter colored, longer kernels, harder and of greater vitreous luster. By grading the grain threshed into two equal parts the heavier weighed 64 pounds per bushel.

No. 5642, Yellow Gharnovka. ("Triticum durum, from Ambrocievka, twenty miles northeast of Taganrog in Don Territory, Russia"). On July 9 considerable smut was noticed in this variety. The awns or beards were long and abundant. Grain darker colored, more plump, or not quite so shrunken, and of much greater vitreous luster than the original seed planted.

No. 5643, Gharnovka. ("Triticum durum, from the same place as the preceding number"). When harvested the awns stood at right angles to the heads making the grain somewhat disagreeable to handle. The grain is of the same color and luster as the original planted, but the kernels were decidedly smaller, with an increase in weight per bushel.

No. 5644, Velvet Don. ("Triticum durum, Chernouska of some reports, from the same locality as the above"). Heads with velvet chaff. Grain was lighter colored, of greater vitreous luster and longer kernels than the original planted.

No. 5645, Black Don. ("Triticum durum, Chernokoloska of some reports, from the same locality as the above"). Awns or beards were partly black. Grain much lighter colored, more plump and of greater luster than the original planted. After the threshed grain had been graded into two equal parts the heavier grain weighed 65 pounds per bushel.

No. 5646, Gharnovka, from Taganrog. ("Triticum durum, from Taganrog, Don Territory, Russia"). On July 9 a few heads of smut were noticed. The threshed grain of this variety is practically of the same appearance in every respect as the original planted, unless it be lighter in color.

TABLE OF COMPARATIVE YIELDS.

| Number and Name | Grain Per Acre. Pounds | Straw Per Acre. Pounds. Stubble 0.2m High | Weight Per Bushel | Weight Per Bushel of Seed Planted | Average Height of Plants. Metres. | Date of Planting. April | Date Above Ground. May | Date of Heading. July | Date of Harvest. August |
|---|---|---|---|---|---|---|---|---|---|
| 4277 Nicaragua | 1078 | 3980 | 62.5 | -- | 1.07 | 27 | 7 | 10 | 5 |
| 5639 Kukanka | 1855 | 6133 | 62 | 64 | 1.57 | 26 | 4 | 2 | 5 |
| 5642 Yellow Gharnovka | 1640 | 4980 | 63 | 60 | 1.44 | 25 | 8 | 5 | 5 |
| 5643 Gharnovka | 1860 | 5730 | 63 | 62 | 1.37 | 27 | 8 | 5 | 5 |
| 5644 Velvet Don | 1893 | 6476 | 63.5 | 63 | 1.47 | 27 | 6 | 3 | 5 |
| 5645 Black Don | 1984 | 5930 | 64 | 63 | 1.40 | 27 | 5 | 3 | 5 |
| 5646 Gharnovka | 1907 | ---- | 64 | 63 | 1.37 | 27 | 5 | 2 | 5 |

### EXPERIMENTAL GRAIN PLATS.

Seven varieties of barley were grown in small plats of approximately one-tenth acre each, and one of these, the Hanna, was grown in a larger field trial of one-half acre. The results on the small plats are reported in the accompanying table.

The Bohemian and Hanna barleys were grown from seed furnished by the U. S. Department of Agriculture. The Bohemian came from Schurazenburg, Bavaria, and the Hanna from Kwassitz, Moravia, Hungaria. We could detect no varietal difference between these varieties. Both have the same season, and yielding power, and both show a tendency to drop the awns or beards at maturity which makes them less disagreeable to handle.

The Hanna is a famous European brewing barley. In a larger field trial of one-half acre it was drilled about three inches deep on April 22, using at the rate of 80 pounds seeds per acre. It received one irrigation on June 24, and was harvested July 25. The yield per acre was 1892 pounds, or at standard weight of 48 pounds per bushel, 39.4 bushels per acre. Our first season's trial indicates that this variety is well adapted to Colorado conditions.

The other varieties given in the table were from seed which had been previously grown at the College.

The oat crops are of some interest. Three new varieties are reported in the table. The varieties from Finland were a little earlier than the others, and one of them produced a large yield. There is a strong prejudice against black oats on the part of our farmers because the wild oats have become such a troublesome weed, and the seed mixed with other grain makes it less valuable. However, the black cultivated oat need not be mistaken for the wild variety, and while it might not pay to raise black oats for our markets, there is no good reason why a farmer should not raise them for his own use if he can obtain a superior yielding sort. The black oats raised from Colorado seed produced a much larger yield than any of the others which were raised under the same conditions, giving 71 bushels per acre, while the yield of the North Finnish variety was 60.5 bushels, and of our best white variety, the Silesian, was 52.4 bushels per acre. However, the Silesian oats planted on a larger area of alfalfa land, gave a fine crop. There was about eight acres in a field which yielded 497.5 bushels, or an average of 62.2 bushels per acre machine measure, and the oats weighed 37 pounds per bushel. On a selected and measured acre in this field the yield was 82 bushels by measure and 87 bushels by weight.

The Russian speltz reported in the table was grown from seed furnished by the U. S. Department. We also purchased 300 pounds of seed which was raised by William Lindenmeier near Fort Collins, and planted three acres of land with it. This field was irrigated June 24, and harvested July 27, yielding 181 bushels, machine measure. The crop weighed 5,386 pounds, which would make the weight per bushel 30 pounds, as it came from the machine only partially cleaned.

### BROADCASTING VS. DRILLING GRAIN.

An interesting case of the relative effects of broadcasting and drilling the seed was noted on the experiment plats in 1901. On the plats where the effects of differing amounts of Nitrate of soda upon wheat and oats was being studied, the seed was broadcasted and harrowed instead of being sown with the grain drill.

The seed began to germinate fully a month after planting and then only a small per cent. came up. The plants which came up late did not have time to form sufficient root system to resist the dry weather which followed, and part of the oat plants dried up without maturing. On account of the late germination of the seed, the weeds got ahead of the grain and helped smother the plants coming up. This resulted in a total failure of the crop. Those plants which came to maturity showed absolutely no difference in growth on the fertilized and unfertilized plats.

B. C. BUFFUM,
Agriculturist.

SOME OF THE EXPERIMENTAL GRAINS—1901.

| | Weight of Grain per Acre. Pounds. | Wgt. of Grain & Staw per Acre. Pounds. | Length of Heads. Metres. | Height of Straw. Metres. | Length of Stubble Metres. | Amount of Seed Planted per Acre. Pounds. | Date of Planting. April | Date Above Ground. May | Date of Heading. June. | Date of Harvesting. July | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Barley, Beardless | 1344 | 2688 | .09 | 1.05 | .17 | 95 | 27 | 5 | 25 | 26 | Heavy heads; best hulls barley in the plots. |
| " Dakota Silver | 1791 | 3582 | .08 | 1.13 | .19 | 95 | 27 | 5 | 25 | 26 | More tall than preceeding. |
| " Black | 1009 | 3183 | .08 | .85 | .17 | 95 | 27 | 5 | 25 | 26 | Bearded; Very short straw. |
| " Giant White—Salzer | 1372 | 3628 | .07 | .97 | .18 | 95 | 27 | 5 | July 2 | 26 | A late, tall, beardless, small-headed variety. |
| " Mansbury | 2081 | 4951 | .07 | 1.14 | .18 | 95 | 27 | 5 | June 25 | 26 | A very handsome barley, tall and erect, bearded, six-rowed. |
| " Bohemian, from Schurazenburg | 2294 | 5026 | .12 | 1.06 | .18 | 103 | 27 | 6 | 25 | 26 | A two-rowed, bearded, brewing variety. |
| " Hanna, No. 5793 | 2266 | 4957 | .11 | 1.09 | .18 | 106 | 27 | 5 | 25 | 26 | Similar to preceeding, long heads. |
| Oats, Russian, No. 2800 | 1289 | 4602 | --- | 1.43 | .18 | 103 | 27 | 7 | July 9 | 31 | Straw matures late. |
| " Black (Colorado Seed) | 2272 | 6448 | --- | 1.36 | --- | 59 | 27 | 4 | 9 | 31 | A late variety, slender straw. |
| " North Finnish, Black, No. 5739 | 1936 | 5808 | .35 | 1.43 | .25 | 77 | 27 | 6 | 2 | 26 | An earlier variety; very coarse straw. |
| " Forneo Finnish, Black No. 5518 | 1450 | 3819 | .34 | 1.40 | .25 | 92 | 27 | 6 | 2 | 26 | Much earlier than Selesian; some rust. |
| " Selesian | 1677 | 4595 | --- | 1.44 | --- | -- | 27 | 4 | 5 | 31 | Sixty per cent. of heads ripe when harvested. |
| Speltz, Russian, No. 2959 | 861 | 3934 | .08 | 1.30 | .22 | 85 | 27 | 6 | 5 | 26 | Straw matures from base; in the dough when harvested. |
| Rye, Prolific Spring | 1570 | 4710 | .11 | 1.36 | .27 | 85 | 27 | 6 | June 21 | 26 | Heads well filled; fine stand. |

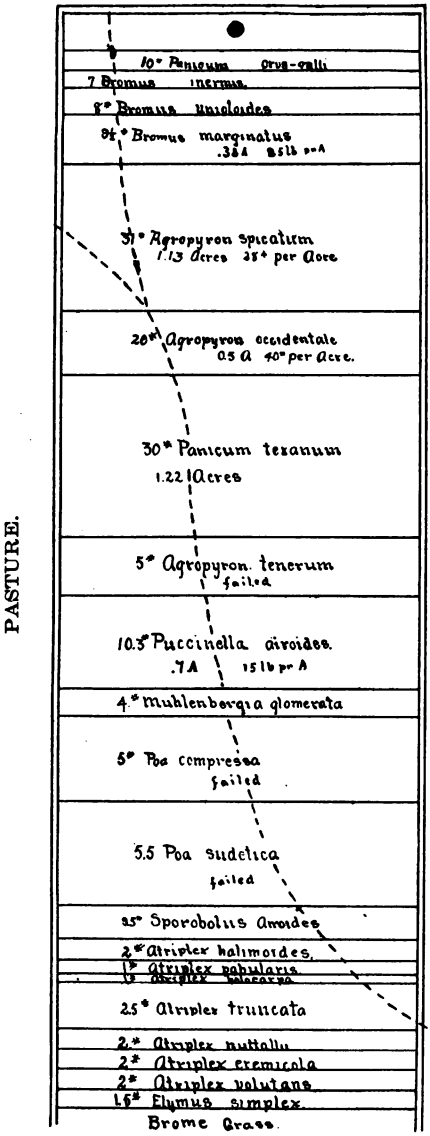

PLATE VI.

Dotted line represents an Alkali Slough.

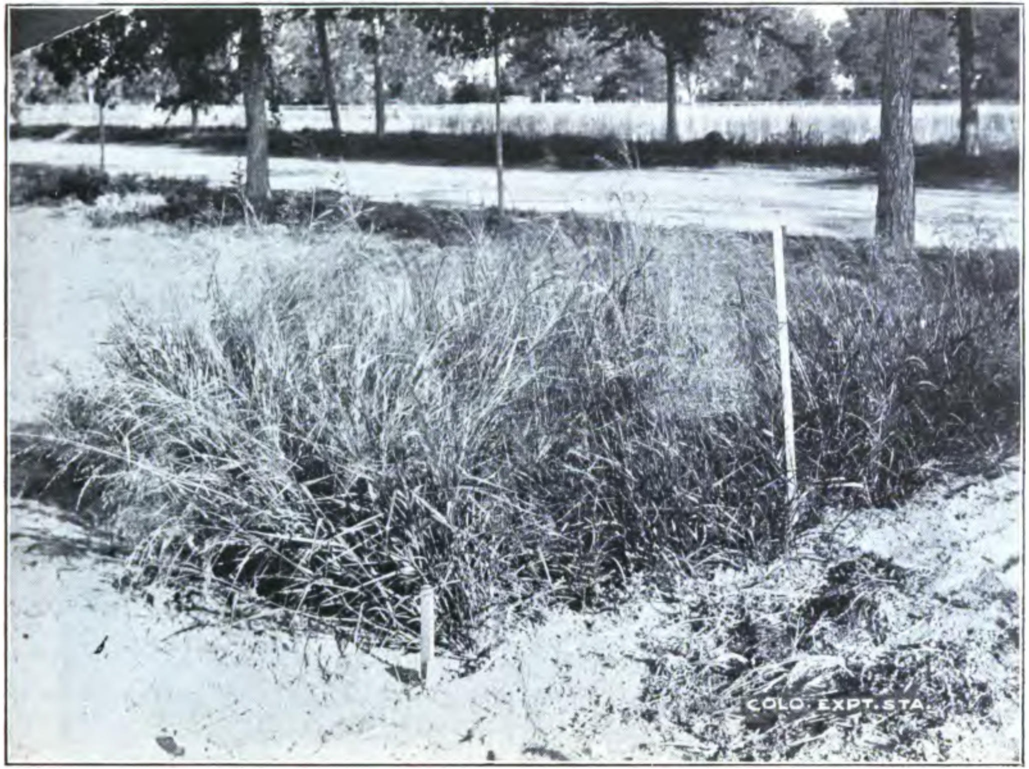

PLATE VII.
Plat No. 99. Eragrostis neomexica( Mexican Crab Grass). August 22, 1901.

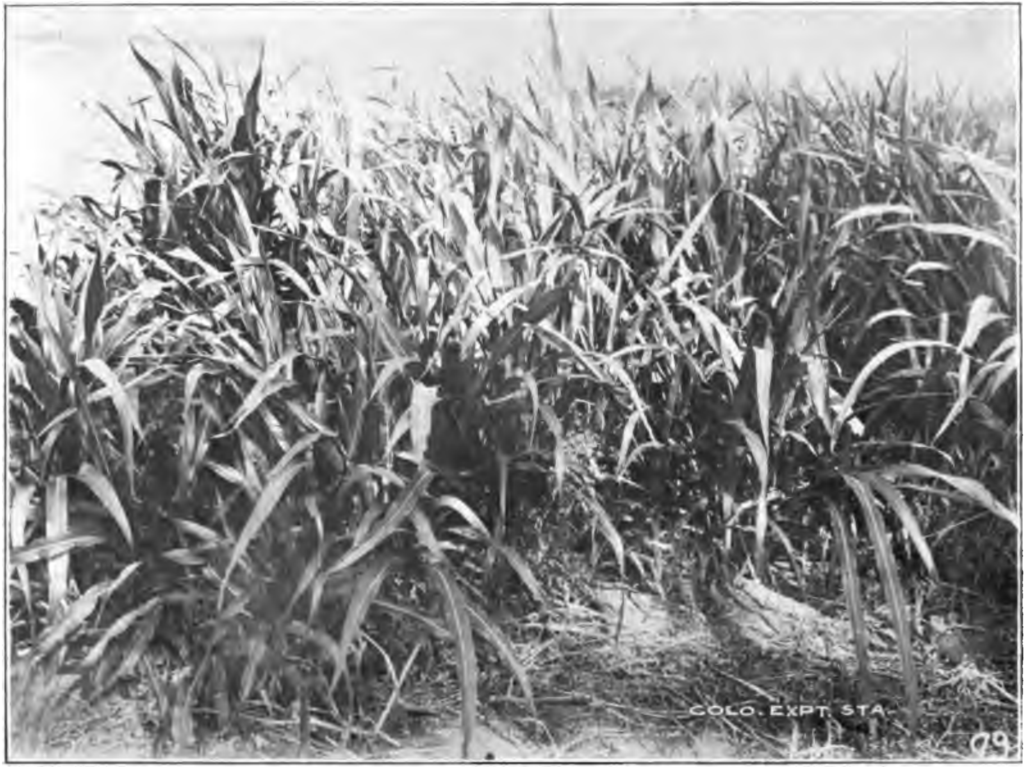

PLATE VIII.
Plat No. 92. Euchlaena Luxurians Teosinte. August 31, 1901.

# A REPORT OF THE CO-OPERATIVE GRASS AND FORAGE PLANTS EXPERIMENTS WITH THE U. S. DEPARTMENT OF AGRICULTURE AT THE COLORADO AGRICULTURAL EXPERIMENT STATION, IN 1901.

BY A. H. DANIELSON.
Assistant Agriculturist.

In the spring of 1901 a great number of species of grass seeds were received from Prof. A. S. Hitchcock of the U. S. Department of Agriculture, to determine their adaptability to Colorado. Of these grass seeds, the larger quantities were planted in an eight acre field, in the middle of May, as field trial, and a small quantity of each was also planted in small plats in the grass garden about the first of June. In spite of the frequent rains during May and June very few made any sort of stand, and a great many did not germinate at all.

## THE GRASS GARDEN.

A plat of ground was divided into small plats 8x10 feet, with 2-foot alleys between them. The ground had been in Brome grass for three years, and after the grass was started in the spring, was plowed deeply and again cross plowed. The plowed soil was then disc-harrowed again and again; harrowed with a common harrow several times and all the Brome grass roots dug and removed by hand. A heavy rain amounting to half a foot on May 20-23 was followed by several light showers until after another soaking rain the soil was well saturated, when on the 1st of June the seed was sown by scattering over the plats and raking it in well. During June frequent rains kept the surface moist, making unusually favorable conditions for the seed to germinate. The weeds of course proved to be more ambitious than the grasses planted, so beginning with July 1 the plats were weeded by hand and all weeds and plants except the variety planted removed. Part of the garden was watered with hose and sprinkler occasionally throughout the month.

It appears that slight differences in soil and method of planting have great influence on the germination and growth of grass seeds. The same seed which made good plants in the field failed to germinate at all in the grass garden. Different methods of planting, and early, late and fall planting will be tried, however, until we discover the right way, for we are determined to get a good stand with all the grasses and forage plants possible.

For convenience it has been thought best to divide the species growing in the grass garden into classes: Those that made a good growth, a moderate growth, and those that made little growth or died out, and those which never germinated.

### THE FOLLOWING SPECIES GREW WELL.

Plat No. 53. Panicum crus-galli—Japanese Barnyard Grass. Seed from Amherst, Mass., planted very thickly. July 10, up; July 22, one of the most luxuriant plants in the plats, entire plat covered and 20 inches high. Sept. 28, harvested; seed ripe and saved. Weight of cured hay from 80 square feet, 31.6 pounds, or at the rate of 8½ tons per acre. Weight of seed 2.5 pounds.

Plat No. 99. Eragrostis neomexica—New Mexico Crab Grass, an annual. Seed from Metcalfe, N. M. July 1, up. July 22, fine stand and very thick, 12 inches high. Aug. 31, the finest appearing grass in the plats; slender stems clothed with abundant foliage, has been heading for two weeks but seed is not yet ripe. Average height 36 inches, tallest plant 51 inches high. Oct. 4, yet unaffected by frost, seed ripe and shelling out. Oct. 19, harvested, weight green 22.9 pounds, seed threshed out 0.8 pounds. The seed does not ripen all at once and there is a great deal left on the stems which may ripen later when dry. (Shown in Plate VII).

Plat No. 92. Euchlaena luxurians—Teosinte. Seed from Texas Seed & Floral Co. June 14, well up. July 22, very thrifty, 16 inches high. Aug. 31, growing well, good stand, leaves resemble those of corn. Average height 30 inches, highest 47 inches. Seems very hardy, not injured by frost at all by Oct. 4. By Oct. 19 totally killed by frost and dry; harvested. (Shown in Plate VIII).

Plat No. 50. Bromus secalinus—(Cheat) (G. & L. Mont.) June 10, up. July 22, very good stand and thrifty, 4 to 12 inches high. Aug. 22, thrifty, close tufted mat, height 4-8 inches. Aug. 31, tops eaten and damaged somewhat by grasshoppers.

Plat. No. 68. Elymus Canadensis—Canadian Rye Grass from Shear, Colorado. July 2, up fairly well. July 22, fairly good stand, looks promising; 4-8 inches high. Sept. 15, a few heads have produced seed. March 11, 1902, the fall planting is coming up thickly, 1-1½ inches high.

Plat No. 56. Panicum milliaceum—Broom Corn Millet, from Potomac Flats, D. C. June 10, up. July 22, full stand, 8-4 inches high, just heading. Aug. 22, seed fully ripe and plants drying up, average height 17 inches. Sept. 21, harvested and seed saved. Weight of dry hay 1.6 pounds. Seed 0.7 pound.

Plat No. 88. Elensine coracana—African Millet, from A. B. Leckenby, Washington State. June 14, up. July 22, very good stand and thrifty, 12 inches high. Aug. 31, has been heading for the past two weeks but seed is not yet ripe; claw shaped heads on end of scape. Average height 16 inches, highest 24 inches. Sept. 28, harvested, seed has been ripe for some time. Weight of partly cured hay 17.4 pounds, seed 2.5 pounds.

Plat No. 59. Sporobolus cryptandrus—Drop Seed from Shear, Colorado. July 22, just coming through the ground very thickly. Sept. 28, a good stand but very short. Forms a sod, very caespitose.

Plat No. 54. Panicum texanum—Colorado Grass, Texas Millet, from H. L. Bentley, Texas. July 6, up. July 22, good stand at one end of plat. Better success in field plat.

Plat No. 51. Bromus unioloides, from M. W. Johnson Seed Co., Atlanta, Ga. June 14, up. July 22, good stand at one end of plat. Beginning to head, 8 to 12 inches high. Aug. 22, seed ripe, falling off; plants 15 inches high.

### THE SPECIES WHICH MADE ONLY A MODERATE GROWTH.

Plat No. 70. Elymus ambiguus—July 2, above ground. July 22, up fairly well, 4-8 inches high.

Plat No. 60. Sporobolus wrightii—Saccaton, from Griffiths, Arizona. July 6, up. Sept. 28, a few good plants about 8-12 inches high.

Plat No. 55. Panicum bulbosum—Alkali Saccaton, from Potomac Flats, Washington, D. C. July 5, up. July 22, a few scattered plants but the greater part just coming up. Oct. 19, damaged considerably by grasshoppers.

### THE FOLLOWING MADE LITTLE GROWTH OR DIED OUT AFTER COMING UP.

Plat No. 100. Cynocurus cristatus—Crested Dogs Tail, from I. W. Woods & Son, Virginia. July 1, up; died out later.

Plat No. 95. Boutelona oligostachya—Blue Grama, from Griffiths, Cochise, Arizona. Oct. 15, a few plants in evidence.

Plat No. 96. Calamovilfa longifolia—From Grand Haven, Mich. July 1, up; died out.

Plat No. 90. Agrostis stolomifera—Creeping Bent Grass, from Wood, Stubbs & Co., Kentucky. July 1, up.

Plat No. 85. Festuca arundinacea—Red Festuca, from A. B. Leckenlay, Walla Walla, Washington. June 14, up. Oct. 15, a number of plants, species uncertain.

Plat No. 84. Festuca rubra—Red fescue, from Peter Henderson, New York, July 1, up.

Plat No. 80. Festuca durinscula—Hard fescue, from Peter Henderson, New York. July 1, up.

Plat No. 76. Poa nevadensis—Nevada Blue Grass, from A. B. Leckenby, Walla Walla, Washington. July 1, up.

Plat No. 75. Poa laevialimia—From A. B. Leckenby, Washington. July 1, up.

Plat No. 74. Poa trivialis—From Peter Henderson, N. Y. July 1, up.

Plat No. 69. Elymus glaucus—(G. & L. Mont.) July 2, up.

Plat No. 65. Elymus glabrifolius—Smooth leaved rye grass, from Texas. July 2, up.

Plat No. 64. Elymus virginicus submuticus—Short-awned rye grass, from A. B. Leckenby, Washington. July 2, up.

Plat No. 63. Agropyron spicatum—From A. B. Leckenby, Utah. July 2, up. (This species did much better under field culture.)

Plat No. 62. Agropyron occidentale—From Elias Nelson, collected near Wymore's ranch on the Big Laramie River, Wyoming, Aug. 24, 1900. July 2, up. (Under field culture this species made a good stand in places.)

Plat No. 49. Bromus richardsoni—Richardson's Brome Grass (G. & L. Mont.) June 14, up.

Plat No. 48. Bromus richardsoni pallidus—Richardson's Brome Grass, (G. & L. Mont.)

### THE FOLLOWING SPECIES DID NOT GERMINATE.

Plat No. 98. Deschampsia caespitosa—Tufted Hair Grass. (E. Nelson, Wyoming.)

Plat No. 97. Dactylotenium australensis—Button Grass, from Potomac Flats, D. C.

Plat No. 94. Ammophila arenaria—Beach Grass, from Provincetown, Massachusetts.

Plat No. 93. Calamagrostis canadensis acuminata—From E. Nelson, Wyoming.

Plat No. 91. Alopecurus pratensis—Meadow Foxtail—From Wood & Son, Richmond, Virginia.

Plat No. 89. Beckmania erucaeformus—Slough Grass, (Griffith & Lange, Mont.)

Plat No. 87. Puccinellia airoides—From E. Nelson, Wyo. (This species made a fair growth under field culture.)

Plat No. 86. Festuca ovina—Sheep Fescue, from Nongesser & Co., New York.

Plat No. 83. Festuca kingii—King's Fescue, from A. B. Leckenby, Walla Walla, Washington.

Plat No. 82. Festuca heterophylla—Various leaved fescue, from D. Lendreth, Philadelphia.

Plat No. 81. Festuca thurberi—Thurber's fescue, from Shear, Colo.

Plat No. 79. Poa macrantha—Seaside Blue Grass, from A. B. Leckenby, Wash.

Plat No. 78. Poa wheeleri.

Plat No. 77. Poa lucida—Shining Blue Grass, from A. B. Leckenby, Wash.

Plat No. 73. Poa compressa—Canadian Blue Grass, from I. W. Woods & Son, Va. (This seed did not germinate either in field or grass garden.)

Plat No. 72. Poa sudetica—From Paris, France. No. 4334. (Not a seed of this lot germinated either in field or garden.)

Plat No. 71. Elymus condensatus—Giant Rye Grass. (G. & L. Mont.)

Plat No. 67. Elymus simplex—Alkali Rye Grass, from E. Nelson, Wyo.

Plat No. 66. Elymus macounii—Macon's Rye Grass, from E. Nelson, Wyo.

Plat No. 61. Agropyron tenerum—Slender Wheat Grass, from K. M. Iver, Canada.

Plat No. 58. Agrostis canina—Rhode Island Bent, from Peter Henderson, New York.

Plat No. 57. Agrostis alba—Red Top, from Nongesser & Co., New York.

Plat No. 52. Panicularia americana—American Manna, from E. Nelson, Wyoming.

A number of plats were planted with some commercial seed bought in the open market some years ago. Among these the following made fair success, particularly sand or hairy vetch *(Vicia villosa)*:

Orchard Grass, French Rye Grass, Italian Rye Grass, Common Crimson clover, Sand Lucerne, Bee clover, Sand or Hairy Vetch, Velvet Bean, Idaho Coffee Berry or French Pease, etc., European Flax, Johnson Grass.

In the fall of 1901 the grass plats were replanted by opening shallow furrows every six inches, leaving the ground between intact. This is to determine whether freezing the seed during the winter will cause it to germinate more satisfactorily. Early in the spring of 1902 the grass plats were again being replanted by opening furrows across those previously made. This is to see whether early planting is not more successful than late. We are determined to have a representation of all the species possible.

### THE GRASSES AND FORAGE PLANTS UNDER FIELD CULTURE.

A field of over eight acres was planted to many species by drilling or broadcasting, to determine what the grasses would do under ordinary farm methods. A depression runs across the land through which runs the seepage from the fields above during the irrigating season. In course of time the soil in this depression has become strongly charged with alkali. The grass seeds were so planted that part of each plat was wet during the season while the balance was on high ground, not capable of being irrigated.

The seeds of the salt bush, *(Atriplex)* were planted in every possible manner on both wet, alkaline and dry land, but none germinated, at least this season. A wild millet *(Panicum sp.)*

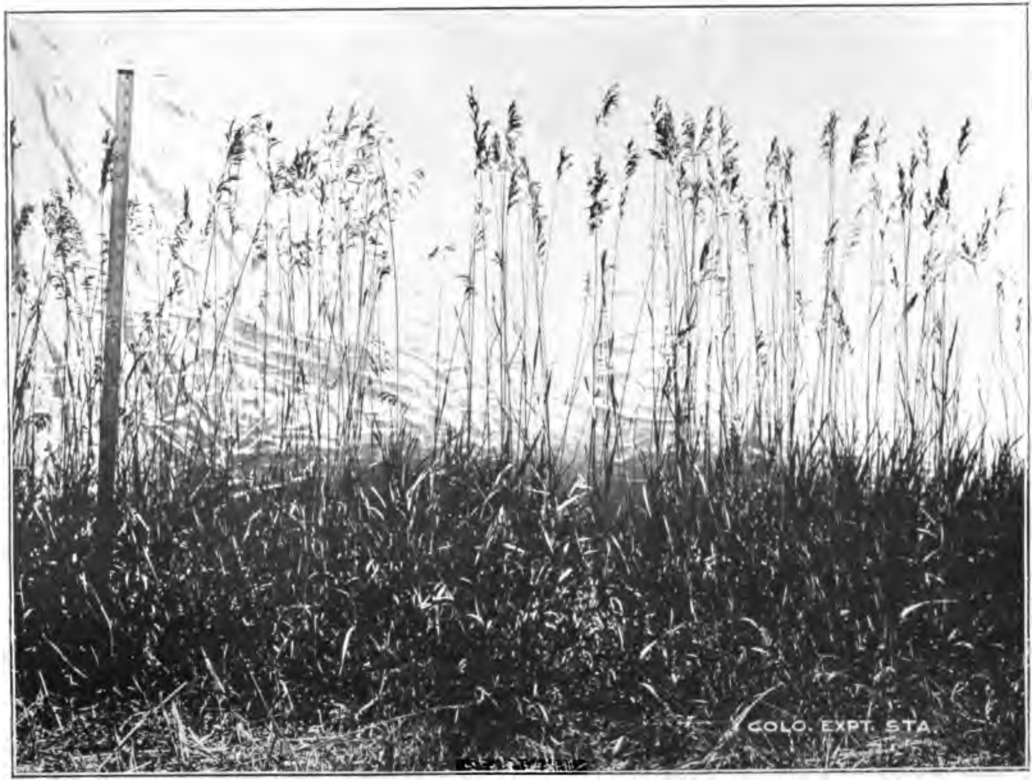

PLATE IX.
Bromus Inermis (Brome Grass).

and a salt sage grows naturally in abundance on this land besides other weeds common on irrigated lands.

The land, which had previously been in a thin stand of Brome grass *(B. Inermis)*, was first disc-harrowed and then thoroughly harrowed with a common harrow. The seed was planted between May 10th and 14th by drilling it in with a common grain drill with grass seed attachment where the shape of the seed permitted, or broadcasted by first harrowing with the drill, sowing the seed and again covering by running over the ground with a drill. When all the seeds had been planted the surface of the soil was thoroughly compacted by running over it with a heavy iron roller. Very heavy rains between May 20 and 22, washed the land quite badly. Frequent rains the following month gave the grass seed a good chance to germinate—also the weeds. The latter became so thick by the middle of summer that the entire field had to be gone over with the mowing machine. In the latter part of summer the field was pastured by cattle.

No definite conclusions can, of course, be drawn from a single season's test, but we have received some valuable hints of promising species. The cultivated barnyard grass *(P. crus-galli)* is eaten greedily by cattle (it was almost dug out by the roots by them) and two species of Brome grass *(B. marginatus and B. unioloides)* seem to do better the first year even than *(B. inermis)*.

Panicum crus-galli—Japanese Barnyard Grass. Seed from Amherst, Mass. Sown very thick on 0.16 acre with grain drill at the rate of 64 pounds per acre, May 14. May 25, up. June 12, about 2-4 inches high. July 2, very good stand, 4 to 10 inches high. When pastured by cattle later in the summer it was very readily eaten by them.

Bromus inermis—Planted May 14 on 0.15 acre at the rate of 48 pounds per acre by broadcasting and drilling; drilled twice and broadcasted between the two drillings. June 12, about 1½ inches high; fairly good stand. July 2, very good stand in places.

Bromus unioloides—Rescue Grass, an annual, from M. W. Johnson Seed Co., Atlanta Ga. Seed planted May 14 by drill; drilled one-half of the land twice. July 2, fair stand in spots. July 18, heading or going to seed in places; 4-8 inches high.

Bromus marginatus—Shortawned Brome Grass. (Nees.) Sown May 13, by broadcasting; land harrowed with drill before and after sowing on 0.38 acre at the rate of 25 pounds per acre. June 12, fairly good stand, 1-2 inches high. July 2, very good stand in places, about 4 inches high. This species has made much better growth all around than B. Inermis.

Agropyron spicatum—From A. B. Leckenby, Utah. Sown by broadcasting on 1.13 acres at the rate of 27 pounds per acre; land harrowed before and after sowing. May 13, planted; June 12, very fair stand, 1-2 inches high. July 2, good stand in spots.

Agropyron occidentale—Collected near Wymore's ranch on the Big Laramie, Wyo., Aug. 24, 1900, by Elias Nelson. Sown by broadcasting on 0.5 acre at the rate of 40 pounds per acre, May 13. July 2, good stand in places, very slow to germinate and plants very scattered.

Panicum texanum—Texas Millet, Colorado Grass, from H. L. Bentley, Texas. Sown May 13 by broadcasting on 1.2 acres at the rate of 24 pounds per acre. June 12, just beginning to show above ground. July 2, fine stand in places. Oct. 23, has made considerable growth this summer and quite matted along the drill rows; plants average about 3 inches apart.

Puccinella airoides—From Elias Nelson, Wyoming. Seed broadcasted on May 11, on 0.7 acre at the rate of 15 pounds per acre. Seed very fine and small; screened twice but too full of straw to be drilled with grass attachment. Managed to drill a small part of the land. July 2, growing well in spots but there are large bare places. July 18, heading or going to seed; 8 inches high. Aug. 22, making fine growth in spots at north end; low densely tufted basal leaves; very slender fine culms.

Muhlenbergia glomerata—From A. B. Leckenby, Walla Walla, Wash. Broadcasted seed on 0.2 acre at the rate of 20 pounds per acre on May 11. June 12, coming up fairly well. July 2, very promising stand, about the best in the field.

Sporobolus airoides—Alkali Fine Top. Two lots of seed, from E. Nelson, Wyoming, and G. & C. Mont. Broadcasted May 10, harrowed with drill before and after sowing. July 2, making thrifty tufts of grass in places.

Agropyron tenerum—Slender Wheat Grass, from K. M. Iver, Canada. Seed like small oats. Planted with drill May 11. Total failure; never germinated.

Poa compressa—Canadian Blue Grass, from L. W. Woods & Son, Virginia. Sown with drill at different depths using small seed attachment, May 11. Did not germinate.

Poa sudetica—From Paris, France. No. 4334. Planted with drill, covering lightly, using grass seed attachment. Not a seed germinated.

Elymus simplex—Alkali Rye Grass, from E. Nelson, Wyoming. Planted May 10. Did not germinate.

## ATRIPLEXES.

None of the following saltbushes germinated this year. They were planted with the drill where the seed permitted or otherwise broadcasted. They were planted by dropping the seed in a shallow furrow, by covering lightly and again deeply; they were planted on wet alkali soil, moist soil free from alkali and on dry land but none germinated.

Atriplex halimoides—Gray Saltbush, from Potomac Flats, Washington, D. C.

Atriplexx holocarpa—Annual Saltbush, from Potomac Flats, Washington, D. C.

Atriplex pabularis—Forage Saltbush, from Elias Nelson, Wyoming.

Atriplex eruncata—Utah Saltbush, from E. Nelson, Wyoming.

Atriplex nuttallii—Nuttall's Saltbush, from E. Nelson, Wyoming.

Atriplex eremicola—Desert Saltbush from E. Nelson, Wyoming.

Atriplex volutans—Tumbling Saltbush, from E. Nelson, Wyoming.

# REPORT OF THE METEOROLOGIST AND IRRIGATION ENGINEER.

The work of this Section of the Experiment Station has been very largely the development of plans that have guided the work for a number of years.

The plans of work originally included a study of irrigation conditions of the whole State, or what was planned to be an irrigation survey. In connection with this an examination was to be made of the various valleys of the State, and the conditions especially regarding water and the use of water leading to a description of the valleys in detail.

The means at the command of the Section have been small so that the general purpose has been very much affected, and it has been necessary to take up some phases which would make no demand for funds. This originally lead to the seepage measurements on the streams, and these have been made during the past season, and carried on over hundreds of miles of streams. These particular investigations have made but small demands for funds, especially as aid has been given by the ditch companies in the different parts of the State, and others interested in the irrigation development. Other investigations which would require funds in addition to our equipment have had to be very largely set aside.

Meteorologicl observations have been continued. They are becoming of increasing importance. The object kept in view has been a study of the agricultural meteorology of the State, with each year's addition it becomes increasingly valuable.

These records are extensive and cover all phases, especially of the meteorology relating to moisture.

Respectfully submitted,
L. G. CARPENTER.

# REPORT OF THE HORTICULTURIST AND BOTANIST

I have the honor to submit the following report of the Section of Horticulture and Botany of the Agricultural Experiment Station for the year 1901.

The work of the Department has followed along the lines laid down in the schedule, as closely as the available time would permit. Mr. Rolfs was detailed to investigate the cause of potato failures and he has devoted a large share of his time to this work. A number of preliminary experiments in treating seed potatoes before planting and of spraying the vines were undertaken. The results of these experiments together with field observations and laboratory studies prove that the failure of this crop in many portions of the State is due to root diseases; the one that is most destructive being a species of *Rhizoctonia.*

Potato plants affected with *Rhizoctonia* present different characteristics according to the nature of the soil, soil conditions and the extent of injury done to the plant by the fungus. Some of the conditions that are familiar to potato growers are, very large vines which may produce either no tubers, a few tubers, or an abnormal number of small tubers. In other instances the potato plant may be killed, thus reducing the stand materially.

A number of important facts new to science have been established and the experiments give promise of practical methods of overcoming these troubles.

The cultivation of potatoes on a large scale in Colorado is restricted to a comparatively few favored localities, which is no doubt largely due to the ravages of fungi. A practical method of combating these plant diseases will mean the saving annually of many thousands of dollars to the farmers of the State.

A report of progress on this work will be published in the near future in bulletin form. The work, however, is far from completion, consequently it will form one of our more important lines of investigation in the future.

The pea disease at Longmont was not as much in evidence this season as last, though it destroyed several fields. Our investigations show that the disease is caused by attacks of a root fungus, *Rhizoctonia* species, which if not the same is closely allied to the one that is so destructive to potatoes. The fungus is present in the soil when the pea seed is sown and there is no practical method of determining its presence except by its effect on the pea plants.

Now that we know what the cause of the disease is, experiments are to be undertaken the coming season to see if it can be successfully controlled or overcome.

Two trips were made during the summer to Delta county, to investigate a disease of apple trees which had attracted considerable attention in one locality. This condition was found to be due to soil conditions and water supply rather than to the attacks of fungi.

A good deal of attention has also been given to root rot of fruit trees that is present in orchards in many parts of the State. The investigation of this trouble will form a prominent feature in our future work.

A bulletin has been prepared on the subject of "Plant Diseases" which is soon to be published. This will contain a resume of the more important diseases of the year, and directions for treatment will be given where possible.

The investigation of the apple industry of the State has proceeded slowly, owing to the lack of time. However, some data has been secured which will be added to as time and opportunity permit.

The condition of celery, mentioned in my former report, known as pithy or hollow stem, was not as prevalent this year as last. Self fertilized seed from both sound and pithy stemmed plants was secured this fall. Should plants from either lot of seed show a difference in either direction, an effort will be made to improve the variety by selection and thus produce a strain of celery that will produce a large per cent. of sound plants.

Arrangements were made with the authorities of the New York Botanical Garden to work over the material in the College herbarium and classify the plants according to the present system of nomenclature. Accordingly the herbarium has been shipped to New York and an expert is now at work on it. It is gratifying to know that this work is now to be completed and that the Flora of the State is to be published in the near future.

Respectfully submitted,
W. PADDOCK.

# REPORT OF THE ARKANSAS VALLEY SUBSTATION, ROCKYFORD.

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Herewith is presented a summary of the work performed in the Arkansas Valley the past season:

The lines of investigation have dealt principally with the sugar beet, the cantaloupe and the tomato.

Leguminous crops have been tested for green fertilizing and forage and grasses for pasture purposes. The experimental orchard has been given due attention.

More than half of the time of the agent has been occupied in taking observations upon questions relating to the agriculture of the Valley, most of which had a bearing on the lines of work above enumerated. This part of the work has been less extended than it would have been were better transportation facilities at hand. For this reason most of the work has been restricted to the vicinity of Rockyford.

The Station land, with the exception of about 15 acres has been under lease to different parties.

The following embraces the lines of investigation with the sugar beet:

1. Means of securing a stand.
2. Success attained at different dates of planting.
3. What effect irrigation, applied at different times and in different ways, has upon the growth, yield and sugar content.
4. The use of green fertilizers, yard manures and nitrate of soda as fertilizers for the beet.
5. Note the growth of beets on alkali soil.
6. General and specific observations upon the depth of planting to secure best results.
7. Effect of hail upon the growth and maturity.
8. Observations upon insects and remedies and upon fungus diseases.

The following embraces the work with the cantaloupe:

1. Treatment of seed for blight.
2. The number of sprayings and the best time to spray for blight.
3. A verification of the work of former years.
4. Note the distribution and extent of the disease, also of insect pests.
5. Time of planting to get earliest maturity.

The following points have been studied with the tomato:

1. Propagation of the plants—what effect the use of different classes of plants may have upon maturity and production.
2. The effect of time of planting upon maturity and production.
3. The effect of fertilizers upon maturity, growth and production.
4. Test of varieties.
5. Pruning and training.

Many specimens of injurious insects have been sent to the

Entomological Department, and the Botanical Department has been advised of any fungus troubles.

Some general notes have been taken upon the spraying and irrigation of orchards and also upon the adaptation of fruits.

Full and complete record was kept of the lambs fed upon pulp for market.

The usual meteorological observations were taken and monthly reports forwarded. Respectfully submitted,

H. H. GRIFFIN,

Rockyford, Colo., Nov. 1, 1901. Field Agent.

# REPORT OF THE PLAINS FIELD AGENT, CHEYENNE WELLS.

I herewith present the following report of work done at the Plains Substation and of the work done as field agent during the past year.

*The Weather.* A record of temperature, wind, rainfall and relative humidity of the air was kept until September 1, when the record of relative humidity ceased on account of the psychrometer being broken. I also acted as volunteer weather observer for the United States Weather Bureau until October 1, 1901. The usual April storm occurred causing serious losses to stockmen between the 1st and 12th of April. After the cold rains during the first part of April very little rain fell until the last of July. Several extensive prairie fires occurred during July. After rains began again there was plenty to keep the grass and crops in good condition until frost. June 11 to 15 was a period noted for storms all over the Plains of eastern Colorado. At Eads a regular tornado occurred; a saloon and school house were destroyed and several other buildings were damaged. The same day a windmill of A. Froelich, sixteen miles southwest of Kit Carson was wrecked by a storm, and the corral and stables of Mrs. A. Hinckley eight miles west of Kit Carson were destroyed by what was reported to be a cyclone.

About June 13, a sever hail storm visited the Vernon Divide, causing much damage to crops and to stock. I saw a frame house which had fourteen holes in the weatherboarding on the west side all made by hail stones during one storm. Some stones went through both weatherboarding and plastering. Animals happening to be exposed were killed.

Hot winds were quite common during June and July.

## WORK AT THE PLAINS SUBSTATION.

*Horticulture.* The fruit trees made a good growth. The effect of the storm water upon the trees shows quite plainly even now. The trees nearest the place where the water comes into the orchard are much larger than those at the opposite corner. The storm water is carried to the orchard by means of furrows, and comes only at times of very rapid rainfall.

*Apples.* Two Duchess of Oldenburg bore about one-fourth bushel of fine fruit. We gathered from later varieties: Ben

Davis, one-half bushel; Winesap, one bushel; Utter's Red, thirteen fine specimens; Jeniton, seven specimens; Romanite, one-fourth bushel; Missouri Pippin, two and one-half bushels. The Missouri Pippin tree received some waste water from the house on account of having its leaves eaten off by grasshoppers. No wormy apples have been found among the specimens produced.

*Plums.* Six varieties fruited. The American Eagle plums were specially fine. The Weaver, Minor, Wolf, Cheney and Rolling-Stone were medium sized with fine flavor. From one Weaver plum tree we picked one-half bushel of fruit.

*Cherries.* Dry weather caused the cherry crop to mature imperfectly. About as many specimens were set as in 1900, but the fruits did not grow so large. Many developed only on one side of the stone. One English Morello tree bore heavily in 1900 and then died to the ground. It threw up a vigorous sprout this year which is believed to be above the bud. All standard varieties of cherries seem to do equally well.

*Gooseberries.* Both Downing and Houghton bore good crops. A few bushes died, apparently from some root disease. I find that nearly all who are raising gooseberries lose some bushes from this cause. Some distance below the crown the root turns black, while between the black part and the crown, the roots do not die for some time after the top has withered.

*Apricots.* Twelve Russian apricots set in 1899 are all vigorous. One fruit was set but was eaten by grasshoppers. It has been almost the uniform experience with the apricot on the Plains that it makes a pretty tree but produces but little fruit.

*Peach Trees.* Nearly all the peach trees survived the winter of 1901, and made a fairly good growth during the summer. They have not yet reached the bearing age.

*Dewberries.*. All the plants reported last year are alive, but none bore fruit this year.

*Crab Apples.* Nine of the ten crap apples set in 1899 are still vigorous, but none bore fruit.

*Pears.* Six trees set in 1899 are still alive. One of the trees blossomed but failed to set fruit.

*Forest Trees.* Of the forest trees reported in 1900, very few have been lost. All made a fair growth in 1901. We have grubbed out all but two rows of the Russian mulberries planted in the main field. These should be taken out next season.

*Flowers.* The Giant Cosmos showed a repetition of their growth and productivity of 1900. They did not produce a flower until after October 1. After that they flowered profusely until a hard frost. Ordinary frosts do not affect them.

### FIELD CROPS.

*Bromus Inermis*. This grass grew well in the early spring, where it was not thickly set. During the summer dry spell it dried up entirely. It would have burnt at any time between June 20 and July 25. But when the rains came, it again revived and made a good growth. When last seen, October 25, it was still green.

*Hagi*. The plants grown in 1900 lived over winter and grew to be twelve to eighteen inches high this year. These are so thin on the ground that the plants are quite woody.

*Sorghum*. Only two varities of the several planted were harvested. These were Early Amber and Early Orange. The other varieties were planted later, after most of the moisture which fell in April had evaporated, so that none grew large enough to cut. Most of the seeds merely germinated.

It was the plan to do the work this year on a practical scale so as to make an estimate of the cost of production. Seven and one-half acres of Early Orange cane were planted, and twenty-nine and one-half acres were planted in Early Amber. On the plats receiving the same treatment very little difference could be noticed in the yield. It happened that the Early Orange was planted first and given one more cultivation than the Early Amber. The yields were as follows: Early Orange, 3,125 pounds fodder per acre; and the Early Amber, 1,470 pounds per acre. The cost per ton is about $2.20, or slightly less than $2 per acre for the sorghum fodder in the shock.

Different parts of the field furnished valuable object lessons on the value of culture at the proper time. But notwithstanding the losses from inability to cultivate at the proper time, the results show that fodder was put in the shock at a very low cost. Work done on this field is up to the average of the country. Hundreds of men lost entire crops by giving up and letting the weeds take their fields when a little labor spent in killing weeds during the dry time would have made them good crops.

*Alfalfa*. About three-fourths of the alfalfa sown in 1897 is dead. This did not produce enough to pay for cutting. Of that sown in 1899 only a little patch growing in a low place was cut.

### INVESTIGATIONS OF EASTERN COLORADO.

The work done in 1901 was a continuation of the work of 1900 with the exception that less time was spent in collecting crop statistics. The greater portion of the time was given to looking for facts which would tend to explain the variation in results obtained in different localities by men of practically the same amount and quality of industry and intelligence.

A map accompanying this report shows the route traveled. 1,800 miles were traveled with a team over a territory approximately 96 to 144 miles. The territory studies include the three valleys of the Republican, the valleys of the Big Sandy, Rush Creek, Horse Creek, and Adobe Creek, and the drainage basins of all these streams.

The location of irrigation plants was noted and enough information concerning each was recorded so that we can get exact data later by correspondence in cases where it would have been expensive to get such information by personal observation. The leading interest of each locality visited was recorded, and men sought out from whom we might gain reliable information by correspondence.

*Grain Farming.* Concerning grain farming, but little can be added to the report of 1900. This is confined, with a few minor exceptions, to the divide between the South Fork of the Republican and the Arickaree, and that part of the divide between the Arickaree and the North Fork of the Republican lying east of the Sandhills. To these settlements with a few individuals near Thurman, Yale, Wallet, are confined the trials of grain raising now carried on in the territory studied. Outside of the two large districts the number who depend upon grain raising is becoming rapidly less each year. In those districts stock raising is becoming more prominent. A partial failure of wheat in 1901 caused many to feel like trying something else. Wheat was not more than a half crop, but corn on sandy land made a good crop wherever thoroughly cultivated. This was one of the years when careful, hopeful and industrious men were paid for their work and pains. A few who experimented were located and their results will be noted later.

## STOCK.

*Small Herds.* By small herds we mean small bunches of cattle cared for by the owner or his family. The size of these herds ranges from a few head to four hundred head. As a rule feed is produced by the owner to feed the weak cattle through the winter and the whole herd through the stormy periods. Eastern Cheyenne, Eastern Kiowa, Northern Lincoln, Eastern Arapahoe, all of Kit Carson, Yuma and Washington counties are included in this, except the river valleys where larger bunches are kept. In this whole territory fodder consisting of sorghum, millet, milo maize or corn were produced. The variety of fodder raised seems to depend more upon the prejudice of the producer than upon the locality, as they are all grown more or less in each neighborhood. Sweet sorghum is becoming standard forage. It can be produced and put into shocks at a cost of about $2 per ton by using ordinary machinery. It is likely that the cost can be materially reduced when the use of up-to-date machinery becomes more general. Even fodder production has not been found profitable upon adobe soil without irrigation.

*Large Herds.* These are found on land where crop raising has proved a failure, or in the hands of old time stockmen who are prejudiced against using the country except as a cattle range. The western part of Cheyenne and Kiowa, the southern part of Lincoln, and the northern part of Otero and Bent, and the valleys of the South Fork of the Republican and the Arickaree are, as a rule, occupied by large herds. The owners of large herds do not generally believe in feeding, and expect their cattle to hustle their feed in winter and summer. Severe losses during hard winters compel the belief that the time is coming when it will pay to feed cattle. This is especially true where the settlement has encroached upon the open range until it is all occupied to the point of being over-stocked. The time was when the valleys were left for the production of hay, but shortage of grass in the summer of 1901 compelled many rich meadows to be used as pasture. Old time cattlemen believe it is more profitable to ship in grain for use of their stock during storms than to attempt to raise fodder or grain by farming. I have been told by some of these stockmen that a man should be fined heavily if he should attempt to put a plow in the ground.

*Improved Methods of Handling Stock.* As the range becomes crowded, men must choose between feeding during the winter, going out of the business, getting absolute control of certain land, stocking it to its capacity, and then increasing the value of their stock, not by numbers, but by improvement in quality. As yet we have met only one man who is trying this plan. His young stock is now the third cross toward purebred and it is easy to recognize them when they become mixed with his neighbors' cattle.

*Ranges.* Losses incurred by stockmen in recent years make prominent the fact that we have some ranges that are fit for use the year round, and some which are safe only as summer ranges. The sandy loam soils and also the ordinary clay loam soils seem to be safe for use at all times of the year, but the adobe land has proven to be unsafe as winter range. In April, 1900, one cattle company lost fifty per cent. of the cattle put on a range where adobe soil predominated. Old stockmen claimed that the character of the soil was responsible for the loss. When the rain came the soil became a mass of very sticky mud, so that when the cattle walked each foot would soon become loaded with from ten to fifty pounds of mud. One of the riders who worked there told me that the course of the drifting herd could be easily traced by the dead animals. The adobe country is excellent summer range, and large sections are used exclusively in that way, the cattle being taken either to the valleys and fed alfalfa during the winter or to other ranges which are safe.

## MISCELLANEOUS OBSERVATIONS.

*Fruit.* Evidence has accumulated showing that plums, cherries and gooseberries can be grown without irrigation by carefully cultivating the soil.

A. E. Tabor, living ten miles southeast of Wray, has produced gooseberries on a commercial scale. His soil is a dark sandy soil. He cultivates carefully; but the efforts at the production of apples, peaches, pears, apricots and grapes without some means of supplying extra water during severe droughts are generally met with failure. However, fine fruits of all kinds have been raised during favorable seasons. For example, the Plains Substation produced some fine apples this year, but the rains happened to come just at the right time to save the fruit. An August drought would probably have caused most of the apples to drop.

The few orchards that are irrigated prove that there is nothing in the climate to prevent success if plenty of water is available when needed for the use of the trees. The places of John Rose, near Seibert; James Howell, near Flagler; John Speirs, near Robb; all show what can be done by irrigation. When I saw the places of Messrs. Rose and Howell, last August, the trees had been recently damaged by a severe hail storm. There were several bushels of fruit on the ground at that time, and what fruit remained on the trees was much damaged. Both these places showed fine fruit in 1900. At Mr. Speirs' last August, his grape vines were heavily loaded with fruit. He is raising considerable small fruit for home use. Peter Eckert, near Thurman, also had a fairly good crop of plums, grapes and cherries this year. Hail is the main source of loss when the trees can be irrigated.

*Timber Claims.* There is nothing to add to the report of 1900, as we have seen very few well kept timber claims this year. Those of Kursidim and Morris (photos of which are shown in bulletin No. 59) are the best that I have seen. These show signs of neglect this year.

*Native Salt Weed. (Artiplex Argentea.)* In the annual report of 1900, I recommended that the native salt weed found near the head of the South Fork of the Republican river, be tested as to feeding value and its distribution determined. Then I suggested that if it seemed to be a valuable forage plant, it should be distributed as widely as our means would permit. Three hundred pounds of the salt weed hay were sent to the Station Chemist, Dr. Headden, to be used in the feeding experiment. He reports that sheep fed the salt weed hay all lost in weight during the test. A full report of the test will be published by the Chemical Department in the near future. In my travels during 1901, I found specimens of salt weed growing in nearly every locality in which adobe soil predominates. Especially if it is alkali soil. Recently I found a specimen near an alkali lagoon two miles south of Fort Collins.

*Australian Salt Bush.* During the year 1900, some plants of Australian Salt Bush were carefully cultivated in a protected corner of a town lot in Burlington, by Hon. T. G. Price. When I looked for them last summer, Mr. Price told me that they had all "winter-killed" during the previous winter. Dr. Headden informs me that Australian salt bush has proved to be an annual in Colorado, although it is a perennial in California.

*Russian Thistles.* I find quite a variety of opinion existing as to the value of Russian thistles as a winter forage for stock. Some claim that thistles are as good as alfalfa for forage, others contend that they are worthless. One man said he liked them for feeding during storms, because as soon as the storm was over the cattle would immediately leave the corrals and hustle for grass; while if millet, corn fodder or cane was fed, the stock would hang around the corral a day or two looking for feed. My own experience indicates that the last mentioned opinion strikes the happy medium and is probably an index to the true value of Russian thistles as forage plants.

*Irrigation.* Only a small part of the region studied this year is irrigated, and from the limited water supply now known, but little can ever be irrigated. No stream flowing through the territory furnishes enough water to make a large ditch pay, or for taking the water up on the divides, where the best water is usually found. Then, where there are good locations for irrigation on a small scale, it is so far from markets that most of the land must be used for raising cheap crops like alfalfa. The best possible use to which such locations can be put at present is as winter quarters for cattle which graze on the uplands during the summer. Most of the irrigated patches are now used in this way. A few use irrigation for making pleasant homes and supplying the family with fresh fruit and vegetables. On the divide it is possible to irrigate small gardens by means of windmills, and this is done by many.

*Windmill Irrigation.* The men who began with a small herd of cattle some twenty years ago, at first had too much water for their stock and so learned to irrigate a small garden. Later, when the herd increased so that it took the water as fast as the windmill would pump it, the gardens ceased to flourish. One calf was said to be equal in value to all the vegetables that could be grown on a little garden patch. Many are now returning to the plan of raising a small irrigated garden. They say that the garden does not pay, but it is one of the luxuries which their present prosperity warrants.

*Irrigation From Underflow Streams.* Nearly all irrigation along the Big Sandy is by means of underflow. Tiling is used for getting the water out of the sand. Between two and three hundred acres are irrigated from the Big Sandy. We have records of many plants showing location, amount of land irrigated and kinds of crops raised.

*Irrigation From Surface Streams.* Nearly all the irrigation in the valley of the South Fork of the Republican is with water from the South Fork of the Republican river. Charles Milleson has forty acres which is sub-irrigated, and there are a few patches near him which are also sub-irrigated. There are fully three hundred acres irrigated in the valley of the South Fork. The Arickaree and its tributaries furnish water for the irrigation of nearly four hundred acres. There are about four hundred acres irrigated in the valley of the North Fork of the Republican river. The valley of Rush creek has about eighty-five acres irrigated. Horse creek and tributaries furnish water for the irrigation of about one hundred and sixty acres. Much of the irrigation water in the southern part of Lincoln county is secured from springs. The underflow of the Plains seems to come to the surface in many places along the head of Rush, Horse, Little Horse, Steels Fork and other creeks in that region. At one place I saw water flowing from a spring at the top of a hill. This spring furnished water for the irrigation of ten acres, and it looked possible to develop still more water from this source.

*Storm Water.* Nearly all the schemes for the use of storm water in irrigation have failed. However, there are a few people who depended on storm water and have succeeded in utilizing it. The Rosenkrantz ranch, where two hundred and fifty acres are irrigated from Dry Willow creek, a tributary to the Arickaree near the Kansas line, is one of the most successful which depends mainly on storm water. The reservoir was broken by a cloudburst in 1900, but it can be replaced at a small cost. James Howell's small plant near Flagler is a success. W. V. Erickson's plant was not yet at work when I saw it this year, as no heavy rains fell last spring to fill the reservoir. The future must test its value.

Men are going into irrigation at the points of the least resistance. Storage of storm water is a problem of the near future. As necessities arise for the use of storm water, it is likely that means will be found for retaining it on its watershed. This will be done in time wherever it will pay.

*Loco.* From March 20 to September 20, I took pains to collect whatever information I could on the subject of loco. Map No. 1 shows the relative distribution of loco plants and is a part of this report. The evidence of stock men was unsatisfactory. The main points of agreement was that cattle, horses and sheep, become either crazy or stupid or both at times, and the witnesses think that eating some species of astragalus, oxytropus, sage or other plants common to the range cause the effects named. In all the region studied we found specimens of loco plants, but in some localities they were much more numerous than in others. There is some evidence showing that families of animals may be adicted to the loco habit; as a cow and all her calves, or a mare and all her colts. The evidence shows that loco plants can be killed by cutting them off below the crown. As the plants produce much seed this course must be persistently followed for a number of years, and thus eradicate them from the pasture. On open range which belongs to everybody, eradication of plants of loco is not a possible solution of the problem, as no one will work when reward is not sure. The subject must be given long and careful study before we shall be justified in giving an opinion upon it. We need accurate records of cases from beginning to end. Most of the evidence begins in the middle of the case with no available history of the animal affected before it was found sick.

*Soil.* During the year 1900 I took very few samples of soil, but observed the soil over which I traveled with a view of selecting samples later. In 1901 I made the taking of soil samples a part of my business. I took forty-five soil samples during the summer, making forty-nine samples in all. These are now stored for use whenever needed. Map No. 1, which is a part of this report, shows approximately the localities from which the samples were taken.

*Soil Influence on Crop Production.* One of the best illustrations of this is found when comparing Eads and Galatea. Near Eads is a small area upon which good crops of fodder are raised every year. At Galatea only 16 miles west of Eads, nearly all efforts at production of forage have proven failures. Eads and Galatea are located in small areas which are bountifully supplied with well water, but are surrounded by a country in which water is not easily found by digging. All the difference which can be seen is in the kind of soil used in trials at crop production. The soil near Eads is a dark sandy soil, while that near Galatea is a very stiff clay ,and may be classed as adobe.

Careful, industrious men have worked faithfully at Galatea, but failures compel them either to turn to stock raising or leave the country. Around the sand hills there is usually to be found a strip of dark sandy land where moderate crops of feed are raised every year while often the clay lands have been abandoned.

*Difference in Climate.* Examine the map and note the small territory near Vernon between the North Fork of the Republican and the Arickaree which is east of the sand hills. This is the field of the most successful attempts at farming which have been made in the whole region of study. Crops average better there than on the divide between the Arickaree and the South Fork of the Republican. The soil certainly does not increase uniformly in fertility as we get further north. The people are of the same class. Rainfall as determined by local observers, is essentially the same. These three factors being so nearly equal, we must look outside the localities for an explanation of the differences. Note that north of the North Fork of the Republican river is a sand hill region about 20 miles wide. West of the Vernon neighborhood is another group of sand hills about 20 miles square. West of both groups, which almost join each other, near the source of the North Fork of the Republican river, is a region fully as large as the two sand hill regions which drains into the sand hills. Water is found in apparently inexhaustable quantities at a depth of 100 to 125 feet in the farming districts. I have noticed that heavy dews are frequent near Vernon in summer, and that hot winds are infrequent when compared to the Plains 100 miles south. Dews occur frequently on the next divide south of the Vernon Divide, but they seldom occur at Burlington and Cheyenne Wells. These facts indicate that it is possible that the success of the farmer on the Vernon Divide is due to the influence of the sand hills on the climate near them.

## PROBLEMS WHICH CONFRONT THE SETTLER.

1. Means of combating insects, especially grasshoppers and potato beetles.
2. Garden irrigation.
3. Water supply and means of raising water from great depths.
4. Forage plants suitable for different localities and methods of producing them cheaply.
5. Destruction of prairie dogs on the public range.
6. Improvement, or introduction of small grain. (For a small district.)
7. The stock industry.
    - (a.) Diseases affecting stock on the range and means of prevention and cure.
    - (b.) Methods of handling stock suitable under new conditions.

Respectfully submitted,
J. E. PAYNE,
Field Agent.